Mechanization—an Anglo Platinum perspective

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The efforts to mechanize narrow reef tabular orebodies unique to this country, are not new. They began in the early 1900s and have over the last century seen varied rates of progress and success. Efforts to mechanize with the use of scraper winches can be regarded as a success. The scraper winch replaced the hand lashing of ore and development waste into hoppers. The initiatives by Anglo Gold and the then JCI to implement trackless mining equipment into these environments had limited success but in general were looked upon as a failure—at least this is the perception. The Chamber of Mines Research Organization (COMRO) in conjunction with various mining houses tried to make a success of the impact ripper. Diamond wire cutting of the stope face is another, which has been tried and tested. The use of high-pressure water to cut rock has also been trialed.

These attempts, amongst others, are just a few of the efforts that have not been successful in the quest to make life at the face safer, more productive and easier for our employees.

Against the backdrop of an emerging South Africa, the associated high expectations of historically disadvantaged people within the country, a strong rand, demands for better safety, lower cost of production and more efficient operations, mechanization has the chance to make a difference to Anglo Platinum’s business. Mechanization has certainly changed the way other commodities such as coal, base metals and diamonds are won from the earth. Mining’s image is still one of people crawling around in stopes—a dirty, ‘low-tech’ business.

Anglo Platinum’s latest journey to mechanize its underground operations began in earnest in 1998 and has enjoyed some successes and failures. The opportunity to change the way mining is done within the company is there. Technologies are evolving, and the implementation of mechanization can certainly assist with the achievement of the goals referred to above. When mechanization commenced, targets were set for the company to achieve but these have been revised in the light of recent events relating to the strengthening rand and a slow-down in expansion plans. However, the intent to mechanize appropriately in Anglo Platinum still exists.

Mining Mechanization—their role and programmes

The role of Mining Mechanization

Mining Mechanization’s role is illustrated in Figure 1. The role of the department as mandated by the executive committee of Anglo Platinum in August of 2002 was divided into four distinct areas:

• Research and development—aimed at identifying both existing and new technologies that may have an application in narrow reef platinum orebodies. The evaluation of potential technologies would lead to further development based on a business case. This would lead to a field trial at an appropriate site.

• Implementation—once proven at a trial site, the technology would be implemented along with the appropriate technology transfer systems to enable ongoing measurement, control and learning.

• Continual optimization—the optimization of the equipment/technology/system is an ongoing function. Observations and learnings are used to continually update designs, any further implementation, the business case and knowledge transfer.

• Supporting systems—the success of any mechanization project is not only dependant upon the technology but a multitude of supporting initiatives:

  • Management systems:
    - Performance databases and tracking systems
    - Project management processes
    - Systems engineering
    - Correct capital forecasting for both replacement and additional equipment requirements
    - Meeting and governance structures
    - Mine planning systems
    - Maintenance, (asset) management systems
    - Communication and information technology

  • Standards and standardization
    - Safety
    - Setting of guidelines and blueprints
    - Information gathering and reporting

  • Commercialization
    - Supplier partnerships or alliancing to drive development of new and existing technologies and reduce costs
    - Agreements to address issues relating to intellectual property (IP)

  • Best practice transfer and reviews
    - Establishing a knowledge sharing and best practice culture through the establishment of best practice communities and technical meeting structures
- Building a library of knowledge for personnel to access
  • Specialist support
    - Constantly be available to assist operations with specialist advice and support
  • Human resources (HR)
    - Technology is relatively easy to develop but it is in the area of HR that actual work needs to be done in order to enable technology to be successfully implemented.

Structure of mining mechanization
Until fairly recently, the department reported to the divisional director responsible for Continuous Business Improvement or CBI (Project Breakthrough). At the end of 2003, with the creation of the Mine Technical Services department, the mining mechanization function started reporting to this domain. The reporting structures are defined in Figures 2 (old) and 3 (a) and (b) (current). As a result of this change and the current focus on cost and organizational efficiency, the role of the department has changed. This will be discussed later in the paper.

The suite of programmes
Mining Mechanization’s focus has been to develop and implement technologies, which will improve safety, enhance productivity, reliability of production and drive the company down the cost curve.
It is clear that within Anglo Platinum there are two areas where technology can be applied:

- a number of older more conventional operations, which are not going to lend themselves to more radical technologies easily. The systems, infrastructure and modus operandi will not easily adapt to some technologies (e.g. trackless), and
- those areas of, as yet, significant undeveloped ore reserves and newer operations where emerging and proven newer technologies can be applied.

The programmes currently being tackled by Mining Mechanization are aimed at both the existing older operations, and the newer and future operations. The following list of programmes categorizes the areas being tackled to address the company needs:

- Research and development
- Conventional mining systems
- Trackless mining systems
- Rockcutting systems
- Logistical support systems
- Management support systems.

**Research and development projects**

The following projects have been addressed as part of the R&D focus:
Extra low profile trackless mining machines aimed at operating in a 1.2 m stopping width—(Figures 4(a)–4(g))

Plasma hole maker—use of plasma cutting to enable the drilling of roofbolt (amongst other) holes of a length, which is greater than the stopping width, without having to continually change rods. (Figures 5 and 6)

Flexi-drill—investigated for the same purpose as the plasma hole maker (Figure 7)

Fuel cells—a look into the application of fuel cells as a means of powering underground mobile mining equipment (Figure 8)

The use of propellants to provide a continuous mining system.

Conventional mining systems
The focus in this area has been to make work both safer and easier at the sharp end (both the stope face and development end) through the provision of drill rigs; leading to increased drilling accuracy and the commensurate increase in advance per blast. The focus in this area includes:

- In stope drill rigs/rigs (Figure 9)
- In stope roofbolters (Figure 10)
- Rapid development advance
  - Development rigs (Figure 11)
  - Face and hopper loading systems (Figure 12)
- Monorail systems for raise development (Figure 13)

Trackless mining systems
The employment of trackless mining systems is well established in the company:

- Amandelbult (16W and 43E—fully mechanized)
- Union declines (hybrid) (Figure 14)
- Frank Shaft (hybrid)
- Waterval (fully mechanized)
- Bleskop (hybrid)
- Lebowa (hybrid)
- Modikwa (hybrid).
Hybrid refers generally to the use of trackless equipment to conduct the development operations and the use of conventional mining systems—jackhammers and scraper winches to conduct stoping operations.

**Rock cutting systems**
- Oscillating disc cutter (conducted in conjunction with the Centre for Mining Research in Brisbane, Australia) (Figure 15)
- Activated drum systems (in co-operation with DBT) (Figure 16)
- Narrow reef miner (in co-operation with RCTS) (Figure 17).

All of the above employ different methodologies with which to cut the rock. The objective of these programmes is to provide a continuous mining system.
Figure 4i. XLP mining layouts—BRPM (South D) room and pillar

Figures 5 and 6. Plasma hole maker

Figure 7. Flexi-drill rig
Figure 8. Fuel cells

Figure 9. Drill rig

Figure 10. In-stope roofbolters
Figure 11. Micro-hydro power suite at Lebowa for development ends

Figure 12. Rapid development advance loading machine

Figure 13. HPE raise monorail development rig
Figure 14. Mechanized roofbolter at union section

Figure 15. Oscillating disc cutting

Figure 16. Activated drum system

Figure 17. Narrow reef miner
Logistical support systems
These systems, aimed at providing better support to mining operations, have focused on:

• The load carry drop system (LCD) for continuous hopper loading (Figure 18)
• Hulme hoppers—a large more efficient, self-cleaning hopper designed to increase ton kilometre per hour tramming efficiencies and thus reduce upstream panel cleaning problems leading to lost blasts
• Hulme skip—working along the lines of the Hulme hopper but used in decline shafts and manufactured to minimize derailing incidents (safety and productivity focused) and improve overall production capability (Figure 19). These skips are used at the UG2 environment because UG2 is renown for its stickiness and packing in the more widely used range of hoppers
• The application of hydro hoisting—screening of the 15 mm from run of mine (ROM) ore underground before it is hoisted to surface and then pumping the 15 mm fraction to surface releases valuable hoisting capacity for either more ore or waste.

Management support systems
These include inter alia:

• A drive on the HR front to address the issues we often forget about when rolling out new technology. The ‘wheel’ shown in Figure 20 outlines those areas where interventions have been initiated to address this critical success factor
• Mine planning systems
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The vision and progress

The vision

The vision of the department has always been to develop a mine for the 2015 environment. This mine of the future will be a rock factory: a rock factory must and has to be a mine that will give Anglo Platinum a significant competitive advantage over other producers. This is how Mining Mechanisation describes the characteristics of a rock factory:

- Cost competitive/enhanced margins
  - reduced unit cost (cost per ounce)
  - supplier partnerships, strategic alliances
  - supplier efficiencies
  - increased volumes
  - quality of operation
    ■ minimal dilution
    ■ optimum stoping width
- Lean and mean
  - organizational structures are appropriate
    ■ trained personnel
    ■ man/job specifications clearly defined and administered correctly
  - balance of technical and operational skills and capability
  - competent and empowered personnel
  - appropriate decision making-systems
  - clear definition and understanding of roles and responsibilities
  - appropriately engineered infrastructure

- good information system and integration aimed at the core business processes and supported by efficient commercial or business systems
- an environment of knowledge sharing and best practice dissemination through effective systems
- mine planning and monitoring systems effectively utilizing control type environments

- Reliable
  - achieve targets
  - good management systems
    ■ planning and reporting
    ■ timeous information to the appropriate level
    ■ timeous decision making
- Equipment reliability
  - engineering and design integrity
  - maintenance competency
- Safe
  - no fatalities
  - culture compliance
  - competent, trained people

Table I indicates how the programmes described above align to achieve the characteristics of a rock factory as described above.

Progress

Each of the programmes/systems outlined above have objectives aimed at achieving improved safety and face advance enhancements in one way or another. Specific details can be obtained from the writer should it be necessary. However, in order to keep the paper focused, what follows, will be an update on relevant progress in those areas deemed appropriate.

Following a dramatic change in the economic climate, some of the more futuristic projects have been shelved: these include rockcutting and hydro hoisting. Others have been shelved for a number reasons-not practical, return for investment not adequate or at a stage in the development cycle which will require technical input and funding from a commercialization partner where one cannot be found, etc.

For the sake expediency, various projects will be linked together to assist with the reporting of progress.
Table II summarizes those projects which have been suspended and those which are continuing.

**Trackless mining systems**

Trackless mining has been operating in Anglo Platinum for a while and has been viewed as having varied success. Where trackless systems have been employed as development systems to access and provide development ahead of stoping operations, they have been classified as successful. At an operation such as Waterval, where fully mechanized bord and pillar operations have been implemented, the initiative has met with various opinions—most of which tend towards ‘not successful’. However, over the last two years since Waterval’s inception there have been many successes:

- a rapid build up to production capacity (Figures 21(a) and (b))
- a very good safety record (Figure 22)

**Lean and mean**

- HR initiatives
- Mechanized miner of the future
- Remuneration systems

**Reliability**

- Communications and IT
  - Data collection
  - Databases
  - Interfaces with existing AP systems (SAP)
  - Control rooms
- Good maintenance management
  - Contracts
  - Supply partnership
  - Technical systems
  - Mine planning and scheduling

**Safety**

- Standards
- Assurance
- Knowledge management and best practice sessions

- a culture of mechanization is now evident at Waterval with a commensurate level of operational standards—roadways, services, etc.

Grade remains a problem—the mine design calls for a mining height of 1.8 m to remove a 0.70 m seam. The concept of ‘mining high and treating low’ has not been achieved through the inability of the operation to effectively scalp off waste underground and remove waste via the use of optical sorting technology on surface ahead of concentrating operations. The employment of dense medium separation (DMS) techniques has not been deemed viable for Waterval.

Figure 23 puts into perspective where Waterval stands on the cost curve compared to other group operations.

Other initiatives such as the fully mechanized (Figure 14) roofbolter for low profile operations has been very successfully implemented along with trackless development operations at Union declines. Bolting rates of between 12 and 15 bolts per hour have been achieved, enabling development to proceed ahead of mining faces, which, with the use of in-stope drill rigs, have achieved face advances in excess of 20 m—even as high as 30 m—per month. Standards and operations here are very good.
Figure 21a. Waterval mine—platinum ounce build

Figure 21b. Waterval mine—tonnage build-up

Figure 22. Waterval mine—LTIs to end 2004
The development of the extra low profile trackless equipment is in its infancy but is already showing a lot of promise. Designed to operate in a stoping width of 1.2 m these extra low profile machines (Figures 4(a)–4(g)) are being trialed at four sites currently:

- Union—Sandvik Mining and Construction (SMC-Tamrock, but a drill rig only.)
- BRPM (South D)—SMC
- Waterval—SMC
- Townlands—RHAM.

The RHAM suite is operating in a breast layout, as is the drill rig at Townlands. The suites at South D and Waterval are operating in a bord and pillar configuration.

The progress overall is satisfactory in that there has been proof of concept. There is good evidence that the equipment is capable of operating in narrow stoping width conditions. Table III summarizes the results achieved by the XLPs at the operations to date and as can be seen they are

<table>
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<th>Actuals</th>
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<th>Feb 04</th>
<th>March 04</th>
<th>April 04</th>
<th>May 04</th>
<th>KPI Plan</th>
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<td>1031</td>
<td>1393</td>
<td>1441</td>
<td>981</td>
<td>1562</td>
<td>2000</td>
</tr>
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<td>19</td>
<td>23</td>
<td>16</td>
<td>18</td>
<td>18</td>
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<tr>
<td>Head grade (g/t)</td>
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<td>4.27</td>
<td>4.38</td>
<td>4.60</td>
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<td>0.23</td>
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<tr>
<td>Mining height (m)</td>
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<td>1.20</td>
<td>1.27</td>
<td>128</td>
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<tr>
<td>Shaft head cost/ton milled*</td>
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<td>85</td>
<td>100</td>
<td>90</td>
<td>100</td>
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<td>73</td>
<td>63</td>
<td>87</td>
<td>87</td>
<td>100</td>
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<tr>
<td>Advance/blast (m)</td>
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<td>1.48</td>
<td>1.4</td>
<td>1.43</td>
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<td>Drill rig holes/hour</td>
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<td>19</td>
<td>15</td>
<td>41</td>
<td>30</td>
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<tr>
<td>Bolts/hour</td>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>6 (1.6 m bolts)</td>
</tr>
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</table>

*Indexed to 100
showing a lot of promise. Version 2 of the equipment designs for both suites is currently in progress. The next step is to finalize the modelling of different mining layouts—a bord-and-pillar layout or a breast-type layout and addressing some equipment design issues. Life cycle cost models have been compiled and are being interrogated for integrity. Plans to roll-out XLPs, specifically at Waterval, as a move from low profile equipment at 1.8 m to XPLs at a 1.2 m stoping width, are making good progress. Figures 5(a) and 5(b) show the breast and bord and pillar layouts currently under consideration for the XLP suites.

At Boschfontein, Capital Development Services (CDS)—an in-house ‘company’ doing mine development work, is achieving well over a 120 m per month in a single end decline. Standards are exemplary, as is their cost per cubic metre.

**Rockcutting**

Rockcutting trials with Anglo Platinum funding input have been stopped. There has been some successes with the activated drum system in terms of pick wear costs but there are still major reliability problems with the system as a whole. DBT, a German-based company, traditional suppliers to the coal industry, are developing systems for hard rock mining and were the commercialization partners with Anglo Platinum in this venture. They have identified design problems and are progressing with the trials at their costs. Results are expected at the end of the year.

The ODC initiative has been stopped—commercialization and maturity of technology have precluded this initiative from progressing further.

The narrow reef miner using traditional compressive cutting methods is working from a mechanical point of view but cutter problems are preventing reliable progress. New cutters have arrived on site and are being tested at present. RCTS—a company out of the old Robbins Raiseboring Company—is running the programme.

**Conventional mining systems**

Stope drill rigs have had varying degrees of successful implementation with success being largely driven by commitment at operations. At Union, Sulzer rigs have achieved good reliable production. The use of Novatek-type jigs at BRPM has met with varied success and at Lebowa, the use of these jigs is gaining momentum.

Again, the use of Novatek development end rigs has had varied success at BRPM. Where they are well employed, advance rates per month have been good. The use of a Mantis drill rig at Brakspruit shaft has achieved highs of 100 m per month with an average of 60 m. Figure 24(a) shows a Mantis drill rig and Figure 24(b) graphs the actual results.

![Figure 24a. Mantis drill rig at Brakspruit](image)

![Figure 24b. Results achieved by the Mantis drill rig at Brakspruit](image)
The use of micro-hydro-powered rigs for flat end development, has been very successful and at Lebowa’s vertical shaft, where compressed air problems due to distance from the shaft resulted in very poor development rates, the hydro powered suite of a roofbolter, drill rig and loader have seen an average rate of 58 m per month being achieved (Figure 26). At Paardekraal, development rates of over 90 m per month have been achieved.

To complement these systems facilitating higher face development rates and to improve safety, the company is currently implementing two types of manless box-holing development systems—a micro hydro powered drilling rig drilling up holes from the cross cut or haulage into the reef raise for blasting using drop raise techniques and a mini raise borer, which is established in the raise and drills down into the crosscut or the haulage.

To complete the system of rapid face advance in the development ends, it is necessary to speed up the loading cycle. The traditional rocker arm loader needs to be phased out and replaced with a more efficient system. Figure 12 is a concept drawing of what is currently being developed to speed up development loading. The loader is designed for use with the load-carry-dump (LCD) system (Figure 18) designed to make the loading of hoppers more continuous as it removes the need to continually having to shunt hoppers around. The employment of the LCD system is starting to prove successful in its application at Amandelbult.

The trialing of Hilti electric drill rigs (Figure 25) has been going well. After some redesign and working with Anglo Gold on the development of the Hilti drill, there is a Mark 4 version on trial at Amandelbult. Results to date are

![Figure 25. Hilti drill rig](image)

![Figure 26. Results of the micro hydro power suite at Lebowa](image)
Continually working with the OEMs to address design problems. Although the Hulme hopper and the Hulme skip have been successful in that they have led to improvement in performance. The Hulme hopper has led to an 18.6% improvement in the tkph index for tramming in haulages when measured against the traditionally employed wide-door hoppers. A payload increase from 3.8 tons to 5.7 tons per hopper has accounted to a large degree for this improved tramming efficiency.

The hydro hoisting application shows tremendous potential on paper but there is still lots of test work to be done to prove this technology in a highly abrasive UG2 environment. The cost of trackless equipment is high and, as such, import exposure is still seen as a risk. As such, Anglo Platinum are working with local suppliers to develop their own equipment. Trackless machinery are aimed at addressing these problems and the current initiatives of entering into strategic alliances with four of the main suppliers of trackless machinery will lead to data gathering, which can be transformed into information and continuous business improvement. Results will lead to data gathering, which can be transformed into effective business information and continuous business improvement. Results will lead to data gathering, which can be transformed into effective business information and continuous business improvement. 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to stick to the original intent has brought success. A change in culture—in this case from the way we do things now to the way we want to do things in the future—does not happen overnight. In coal it has taken a long time to get the levels of productivity required and with these productivity outputs has come tremendous improvements in safety. The question of ‘did the attempts to mechanize the gold mining industry in the mid 1980s and early 1990s stop too early in the life cycle?’ must be asked. Certainly from a retrospective workshop held in Anglo Platinum in 2003 with ex-JCI personnel, it may have been the case. Certainly it has become clear that ‘not one size fits all’ and that one needs to adopt and adapt technologies to fit what Mother Nature provides us with. The papers written in the mid 1980s certainly indicate that the approach to mechanization was thorough and complete. At a recent colloquium held in Rustenburg on ‘Mechanized Mining and Support in the Bushveld Complex’ the vast number of papers allude to the success of the mechanization programmes hinging on the people aspects. The systems of the training and learning that were prevalent in the periods referred to above—such as the GMTC and the like—do not exist anymore. In times of tight revenue flows these aspects of the business have been done away with. Survival has come first. This has, however, left us with skills shortages in times of an expanding industry—as platinum is now seeing.

Within Anglo Platinum, mechanization will only succeed if it is implemented with the support of top management and the desire to stick to the strategic intent. The critical success factors around the mechanization thrust of people, systems and technology must be addressed as part of a complete systems engineering approach. There is little doubt that to mechanize the sharp end of our business is the right way to go. We must continue with the drive to mechanize and support the initiative. The rest of the industry has shown that by sticking to the strategy, the thrust has and is still paying dividends. There are a number of initiatives within Anglo Platinum where we are doing well—the XLPs for instance. Our competitors are also looking at mechanization. They are continuing to aggressively look at rock cutting and a watching brief on their progress will be maintained.

With the exciting challenge of new mines within Anglo Platinum coming on stream over the next five and more years, the time is right to continue with the thrust to find and develop technologies that will enhance our operational productivity, cost base and safety achievements. Continuing with the current thrusts will grow the culture needed for mechanization success.

A number of critical success factors have been highlighted in this paper:

- the support of top management
- strategic alliancing with OEMs
- good supporting management systems
- the necessity of good people and the systems that address the well-being of these important assets
- the creation of an environment that is committed to learning and knowledge sharing, and lastly
- the ability to stick to our strategic intent.

The mechanization thrust in Anglo Platinum has achieved some success. It does, however, have the potential to deliver a lot more. There are some good programmes coming to fruition. The trick will be to have these successes rolled out and bought into by the organization as a whole, ready to put into the appropriate mine—be it an existing or a future mine.

The mechanization thrust will and must continue and it is recommended that the areas of HR development and training need prioritization. In order to attract the correct skills to the mining industry we need to change its image—by using the thrust of mechanization and ultimately automation requiring a more high-tech skill—this can be achieved.

Acknowledgements

My thanks go to the team in Mining Mechanization, those champions at the operations without whose support these sort of projects cannot be conducted and lastly, but by no means the least, to the management of Anglo Platinum, who have supported the initiative. Without the input of all of these people we would not have got so far.

References

