DEEPLAUL, V and BRYSON, M. Mintek, a national resource of minerals processing expertise for platinum ores. *International Platinum Conference 'Platinum Adding Value'*, The South African Institute of Mining and Metallurgy, 2004.

Mintek, a national resource of minerals processing expertise for platinum ores

V. DEEPLAUL and M. BRYSON
Mintek

As a national facility, Mintek's brief is to conduct high calibre research that allows the most effective utilization of South African resources. The research takes two different forms, with the efforts being directed at both high-risk endeavours that may lead to the development or adoption of new technologies or the reapplication of technologies to potential new operations.

Starting in the 80s Mintek began developing a process to upgrade the UG2 ore and invested heavily in projects, equipment and people to service the industry. Some of the highlights of that work that has been conducted here include:

- Development of a milling and flotation process for UG2 ores
- Development of the 'Mintek Process' for maximizing PGM recovery for UG2 ores
- Conversion of the UG2 milling circuits to open circuit
- Development of a robust pilot plant facility for use in plant design studies
- Use of dense media as a waste rejection option
- Use of attritioners in flotation circuits.

More recently, and with the future in mind, the following processes are being researched, some of which have already been commercially applied:

- Development of a flowsheet for Platreef ores
- Use of optical sorting technology for upgrading platinum ores
- Use of a mini-plant for reagent optimization studies.

Each of the highlights listed above will be discussed in the paper.

Mintek, a national resource

As a national facility, Mintek's brief is to conduct high calibre research that allows the most effective utilization of South African resources. The research takes two different forms, with the efforts being directed at both high-risk endeavours that may lead to the development or adoption of new technologies or the reapplication of technologies to potential new operations.

Over its 70-year history Mintek has been involved with a wide range of technology development and implementation into the mining industry. In the high-risk endeavour category one can quote the development of the CIP process for gold extraction, the use of DC arc furnaces for making ferrochrome from chromite fines, the development of control systems for the metallurgical industry, and the development of bioleaching technology for gold and copper ores. All of these projects were started at Mintek and have been commercialized into operating plants. The technical resource base associated with these projects still resides at Mintek.

In this paper the objective is to show how Mintek developed an expertise base in the minerals processing of platinum ores and how this resource base has been fundamental to much of the expansions that have occurred in this industry over the last few years.

Phase 1: Why did Mintek get involved?

The strategic vision in the 70s within the industry was that there was going to be an increased demand for platinum to support the expected growth in the autocatalyst industry as environmental issues became more important. It was considered unlikely that the demand could be met by the depleting Merensky reserves or from the Eastern Bushveld, where significant infrastructure investment would be required. Attention was thus focused on the extraction of the PGM values from the UG2 ore.

At the time the major concern about the UG2 ores was that it would be difficult to treat the concentrate in a traditional matte sulphide process as the Cu, Ni sulphide values were low and the chromite values high. Furthermore, the poor association in certain cases of the PGMs with the base metal sulphides (BMSs) and the small PGM sizes were interpreted as indicating that the concentration of the PGM values into a flotation concentrate would be difficult.

Over an extensive period, Mintek, in conjunction with Lonmin, was able to show that a process could be developed to exploit the UG2 ore commercially. In the process Mintek developed expertise in characterizing the UG2 ore, developed mineralogical and assay techniques, and demonstrated proficient pilot plant building and operating capabilities.

As the UG2 ore became an increasingly important resource in the industry, Mintek continued to invest in understanding the mineral processing of this orebody. Extensive research work in understanding the interaction between the gangue minerals and reagents was undertaken.

At the same time, Mintek invested in understanding particle bubble interactions and developed a bubble size measurement device that was subsequently modified by UCT and has found extensive use in the Amira P9 flotation modelling program.

Much of the development work culminated in the piloting at Mintek of ore from the Western Platinum deposit. The piloting focused on the definition of operating conditions for a larger piloting programme of work to be conducted using 2400 t of ore at the Western Platinum Merensky concentrator. The plant was modified to replicate the pilot flowsheet presented in Figure 1.

The results from the first test run on UG2 ore in a commercial plant are presented in Table I. The concentrate grade and noble metal recovery were marginally lower than those predicted in the pilot runs. From the test results it was concluded that the ore was readily amenable to concentration by the procedure developed on the Mintek pilot plant. This set Lonmin on their way to becoming the industry leader in UG2 ore processing.

Phase 2: Assist Lonplats with implementation of the MF2 and Mintek Process

The successful commissioning of UG2 plants at Western Platinum were used as the basis to plan the expansions that were required to exploit the UG2 ore at Eastern Platinum. An innovative approach to UG2 processing that was used in the Eastern Platinum plant design was the introduction of the mill-float-mill-float (MF2) concept, and the removal of a chromite fraction from the primary rougher tail. Both developments were based on mineralogical observations that indicated that the bulk of the PGM values in the ore were liberated at a coarse grind of 35% -75 µm and there were significant associations of PGMs on the grain boundaries of BMSs. A significant proportion of the PGMs were locked in the silicate phases and required fine grinding for liberation. It was also shown that the chromite grain size enabled the production of a high-grade chromite product by spirals that did not contain significant PGM values.

When the plant did not achieve the predicted performance, Mintek was again approached to assist in

Table I
First UG2 shift results from western plats trial

Date	Shift	Grade of concentrate				Noble metal recovery (%)
		Noble metal (g/t)	Ni (%)	Cu (%)	Cr_2O_3 (%)	
3/12/83	A	406	2.54	1.27	2.92	85.1
	N	309	1.64	0.81	3.94	88.2
4/12/83	A	414	2.42	1.14	3.21	85.4
	N	427	2.64	1.20	3.43	86.4
5/12/83	A	411	2.38	1.10	3.61	84.9
	N	205	2.96	1.96	1.84	78.2
	Average	362	2.43	1.24	3.16	84.7

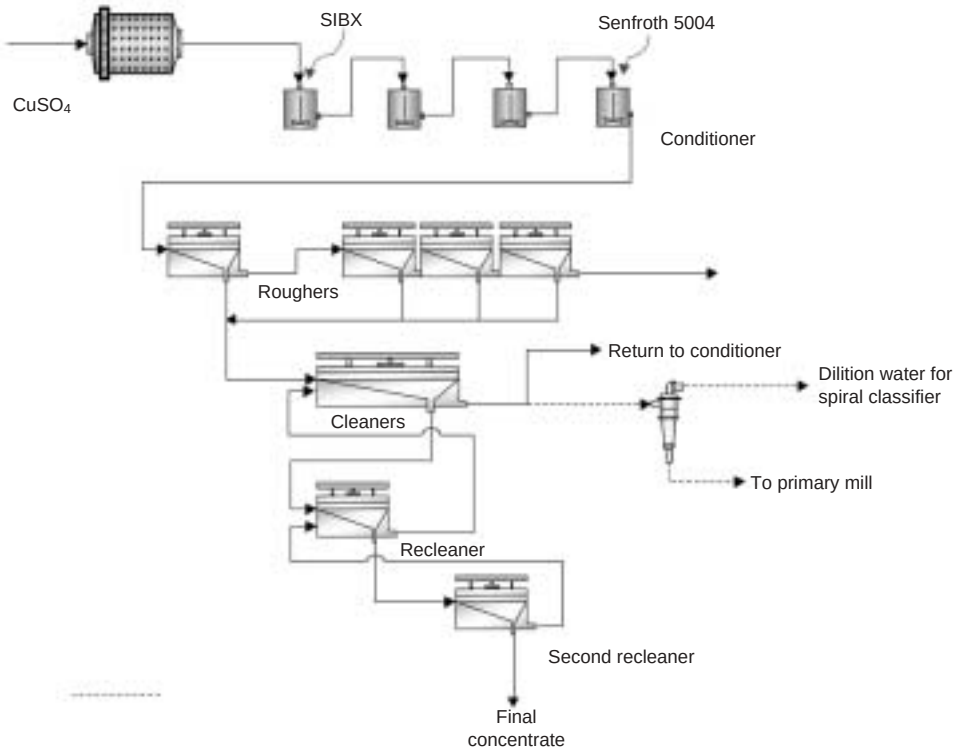

Figure 1. Mill Float (MF1) Pilot plant testwork flotation circuit

understanding the possible causes and to propose a process solution. Extensive sampling campaigns were conducted to understand the behaviour of the PGMs through the plant and it was concluded that changes to the cleaning circuit were required. From laboratory work on plant cleaner tails streams it had been demonstrated that the PGMs could be recovered by the addition of high depressant dosages and the use of long flotation residence times. From this observation was born the concept of the Mintek Process that uses a single integrated cleaning circuit with the production of high and low grade concentrates to improve the PGM recovery to the overall concentrate by up to 5%. 'The Mintek Process' flowsheet is presented in Figure 2.

The concept that there were fast and slow floating PGM and gangue values in an ore was used to design the flotation plant configuration such that the fast floating PGM values were removed via the high grade concentrate, and the slower floating PGM values to the low grade concentrate. The subtleties of the process was the realization that one needed to accentuate the differences between the slow floating PGMs and gangue through depressant addition but one also needed to create the appropriate froth structures to facilitate adequate froth drainage to minimize chromite entrainment into the concentrate. Coupled with this concept was the realization that one should not recycle any streams to the rougher circuit and that one should minimize the recycle loads in the cleaning circuit to ensure high overall PGM recoveries. It was felt that the highest probability of floating the slow floaters was during its first pass through the cleaning circuit and every effort should be made to recover it and, if allowed to recycle, it would probably be lost to an eventual bleed out to the final tail.

At the same time it was also realized that, to run long residence times in the cleaning circuits, one needed very tight control of froth height and air rate to ensure that the pulp carry-over into the flotation concentrate was minimized. Out of this knowledge Mintek developed the Floatstar® platform that controlled operating flotation pulp levels more consistently than previous manual attempts.

Phase 3: Assist new producers requiring metallurgical testwork for bankable feasibility studies

After a quiet period where the then current producers continued development independently, Mintek reactivated its interest in PGM mineral processing flowsheet development when Craton Resources approached Mintek in the mid 90s on behalf of Aquarius, an Australian junior mining company, to assist in the evaluation of some UG2 orebodies in the Kroondal-Rustenburg area.

As a small potential PGM producer, with limited access to capital, Kroondal needed to be innovative in their approach to the mining and metallurgical aspects of the project. Mintek was intimately involved with Dowding Reynard and Associates (DRA) with regard to the metallurgical performance of the process. Through various pilot plant campaigns it was shown that dense media separation (DMS) was a viable process for the rejection of barren waste rock. It was also shown that rod mills could be used effectively to produce grinds of 35% –75 μm and that the bulk of the PGMs was liberated at this grind. It was also shown that the plant could start up with a single stage mill rather than the more expensive option of 2-stage milling.

As Kroondal had difficulties in finding a market for its concentrate, attritioners were installed to enhance the product quality. The Kroondal flowsheet is presented in Figure 3.

This project initiated an intense period of testwork, which is still ongoing today, where Mintek contributed to numerous bankable feasibility and optimization studies with DRA and others.

When undertaking testwork for bankable feasibility studies, an inherent requirement is to develop data of statistical significance as well as to present a process flowsheet and report that are unqualified.

Mintek has been involved with the development of mineral processing flowsheets for many of the expansions in the platinum industry over this period. Some of the projects where our pilot facilities and expertise were used

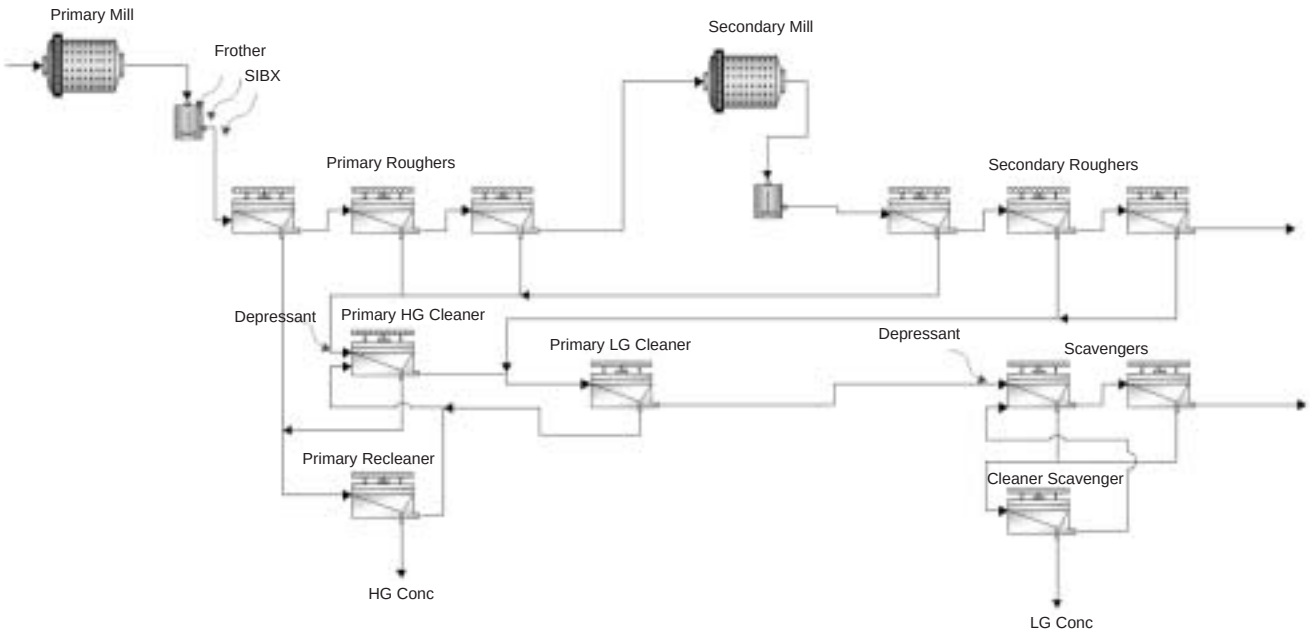

Figure 2. Mintek MF2 process

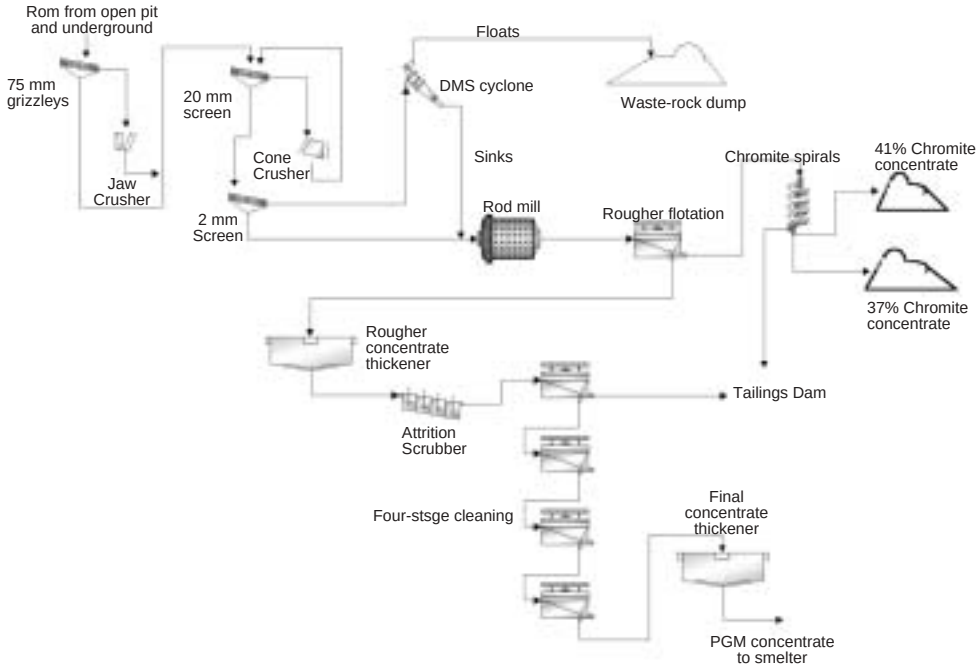

Figure 3. Kroondal flowsheet

include the Karee, Northam, Crocodile River, Marikana, Pandora, Everest South, Two Rivers, Messina, Marula, Panton Sill, Blue Ridge, and Unki studies. Mintek's pilot plant has also been used for on-site plant flowsheet optimization studies.

A significant database of experience at Mintek has indicated that there is no generic UG2 deposit or flowsheet, hence validating the need for piloting testwork. During pilot campaigns, spirals, attritioners, dense medium separators and fine grinding mills have been integrated into UG2 flotation circuit flowsheets, each being supported by the specific mineralogy of the ore or stream being treated.

Phase 4: New technologies

As the experience in processing technology for UG2 matures, process optimization to make marginal incremental improvements in recovery and reduce costs continues. Some of the technology improvements are the move to open circuit secondary milling and the use of optical sorting technology.

Conversion of the UG2 milling circuits to open circuit

Commercial milling circuits normally see mills being operated in closed circuit, with the mill discharge been classified and the coarse product returned to the mill to be reground. Operating mills in this manner is undertaken to achieve energy efficiency whilst achieving product specification. Most of the early MF2 mills were designed and operated in this manner.

Mineralogical and chemical analysis of the secondary float tails showed that it contained a significant portion of coarse unliberated silicates that contained PGMs either locked or attached to grain boundaries. Size and assay investigation of the secondary mill discharge indicated that the chromite had a finer particle size distribution than the silicates. In essence, the chromite having a higher SG than the silicates had a skewed proportion returning via the cyclone underflow to the secondary mill to be reground; hence a dense media effect occurred in the classifying cyclone between the chromite and silicates. As a result of the high recirculating load of the chromite to the mill, the silicates were being displaced in the secondary mill, leading to inefficient milling of the silicates and hence increased PGM losses to the final tail. A schematic of the secondary mill in closed circuit is presented in Figure 4.

In order to overcome the chrome-silica split, open-circuit secondary milling has shown to make significant inroads into reducing the presence of coarse unliberated silicates in the secondary mill discharge. A schematic of the secondary mill in open circuit is presented in Figure 5.

The use of optical sorting technology for waste rejection

Up-front waste rejection in a UG2 plant has two potential benefits: for an operating plant, in which the plant is the bottleneck, the ability to increase the PGM ounce production for a relatively fixed operating cost. The second is to mine more economically and safely by using mechanized and wide mining techniques.

Recent technology advances have allowed optical sorting to be considered for this application. This technology successfully exploits the colour differences between the waste and reef in an ore, and the first commercial installation of this technology in the PGM industry has recently been commissioned.

Figure 6 illustrates the principle of operation and separation. Material being presented to sorter needs to be washed of fines, vibrated to remove excess water, and then presented as a monolayer through the photographic chamber for detection. A preprogrammed algorithm is used to identify the accept and reject streams. An air-jet system is linked to the computer image recognition system and changes the falling trajectory of a single particle, depending on the sort required. The throughput of the sorter is a function of the top size of the particles being treated. The present top size to the commercially installed sorter in the PGM industry is 250 mm, and it is expected that the sorter could handle throughputs of approximately 200 t/h.

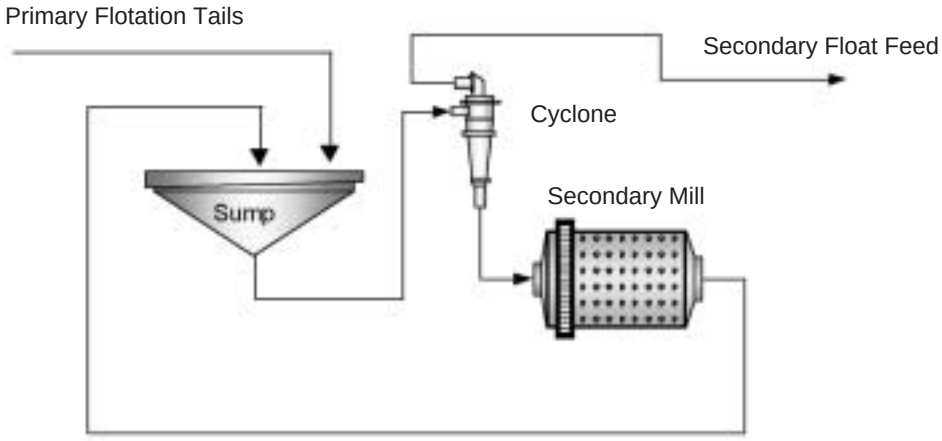

Figure 4. Secondary mill schematic: closed circuit operation

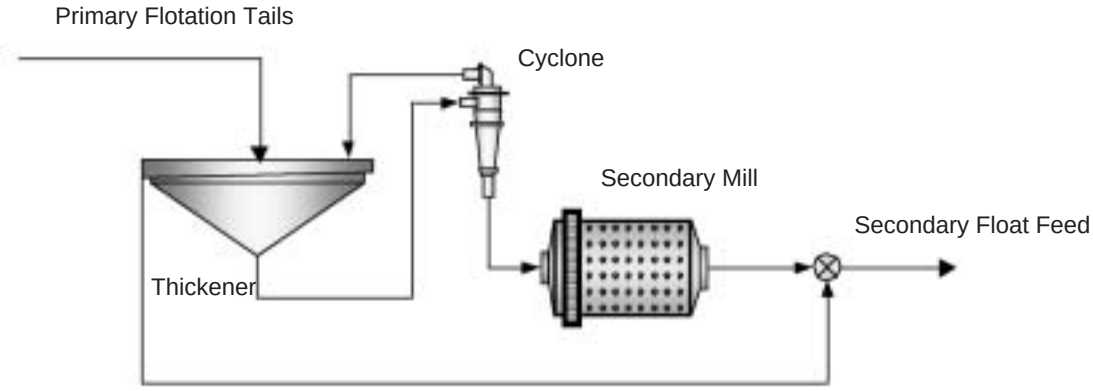

Figure 5. Secondary mill schematic: open circuit operation

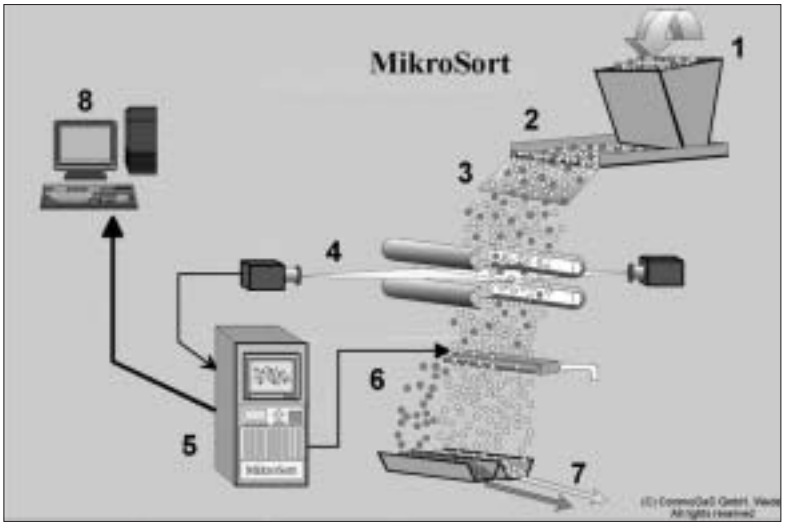

Figure 6. Schematic of ore flow through the optical sorter

Further developments of this technology exploiting optical as well as multi-sensor technology exists and is presently being developed and tested. These advances may potentially have application for the treatment of Merensky and Platreef ores.

Phase 5: Way forward

Mintek has maintained it position as a leader in the PGM mineral processing field by application of its early research and the continued investment in projects to improve the effectiveness of these circuits.

The project areas on UG2 ores that have been identified for active research are the production of very high PGM grade, and low chromite grade concentrates; flotation using non-mechanical type flotation cells; improving recovery from plant streams using ultra-fine grinding techniques;

secondary mill energy efficiency improvements through improved classification and milling conditions; and the development of sorting and concentration technologies.

Exploitation of the low grade Platreef ores has become a target for the local industry. In response to industry interest, Mintek is investigating technology to produce high-grade concentrates from this source, which could find an easier market at existing smelter complexes.

Based on the expertise available at Mintek, industry requested that a skill development course be offered to young engineers and technicians entering the industry. The Introduction to Mineral Processing training course consists of 5 one-week modules: a general introduction to the need for mineral processing, crushing and screening, milling and classification, flotation, and physical separation. The course has a mix of theory, practical experiments, site visits and the completion of formal assignments for each module. Industry experts and vendor presentations are also key to the content of the course being offered. The course format will be changed by presenting specific relavent sections in a short course format

An innovative approach to the undertaking of large generic high-risk research projects with relevance to the PGM industry has been well received by the large platinum producers. The platinum research venture (PRV) has been established as a forum in which PGM industry players can initiate and participate in research projects of common interest.

Conclusion

This year Mintek celebrates a history of 70 years of effort to support the minerals industry. From a very small strategic investment by the state, with the objective of ensuring that this country develops technology that would allow it to remain globally competitive and continue to create jobs, we have grown and changed into a world-class facility.

Mintek is a unique organization as it undertakes both commercial short-term service projects for clients and larger longer-term research projects for the state and consortia. Through doing so, a resource base on PGM minerals processing has been created, and this base is being utilized by many of the local and overseas PGM projects currently being evaluated.