# Journal Comment The Development of Research in the Western Cape

### **Overview**

This volume of the Journal focuses on minerals processing and extractive metallurgy research currently being carried out at the universities of Cape Town and Stellenbosch and the Cape Peninsula University of Technology. This collection of current research presents an opportunity to reflect on the development of these research areas in the Western Cape over the past few decades. The minerals processing activities in the Western Cape go back to the 1970s, at which time impressive new facilities were constructed at the University of Stellenbosch (SU) where Nico Louw and John de Kock were establishing a strong minerals-related research activity. John had moved from UCT where he had begun a small but active research group focusing on coal processing.

In 1978 the then Department of Chemical Engineering at Stellenbosch University split into two, with the spin-off establishment of the Department of Metallurgical Engineering. With the arrival of Frikkie Cloete in 1979 and Jannie van Deventer in 1981, the department's research activities began a strong period of growth, especially in the areas of flotation, ion exchange, and gold adsorption studies.

Many of those involved in these early years later went on to occupy eminent positions. These included Leon Lorenzen (later Deputy Dean), Markus Reuter (now Director of Technology at Outotec), Andre Burger (now Head of Department), Francis Petersen (now Dean at UCT), Steven Bradshaw (now heading up the minerals process research), Chris Aldrich (who led the data-based modelling research), and Victor Ross (Lonmin and Chairman of SAMMRI). In 1996 Jannie van Deventer left for the University of Melbourne and was succeeded by Leon Lorenzen, who took over as department Chairman, continuing to drive mineral processing research with activities ranging from jet mixing to diagnostic leaching.

After his retirement in 1997 Frikkie Cloete was replaced by former graduate Jacques Eksteen, who established a highly successful Western Cape Pyrometallurgical Facility. In 2007 Guven Akdogan succeeded Jacques, and together with Steven Bradshaw and Christie Dorfling, who joined the department in 2009, continued to grow the research activities across a broad front, with specific focus on hydrometallurgy, pyrometallurgy and CFD. Upon Chris Aldrich's departure, Lidia Auret assumed responsibility for the academic activities of the Anglo American Platinum Centre of Excellence in Process Monitoring. (http://processengineering.sun.ac.za/researchthemes/mineral-processing). This centre, formed in 2008, continues to provide custom solutions for the industry's data monitoring needs.

Minerals processing at UCT also began to grow vigorously in the late 1970s, based in the Department of Chemical Engineering. In 1978 the late Geoff Hansford started a research group in bacterial leaching, working closely with similar groups at Gencor and NIM (now Mintek). In 1980 Cyril O'Connor began a fledgling activity in flotation, this group being the forerunner of what has become the Centre for Minerals Research (www.cmr.uct.ac.za). This flotation initiative grew strongly, thanks mainly to the excellent

support from many people, too numerous to name, at the former NIM, AARL (now Anglo American Technical Solutions Research), Gencor, Gold Fields, Anglovaal, Senmin, and many others. In 1983 J.P. Franzidis joined the Department and, given his previous experience working with the legendary David Horsfall of Anglo American Coal Division, rapidly developed a strong activity in coal research. One of his early postgraduate students was Martin Harris, who is today a senior member of staff at the CMR and plays a critical leadership role in many of its research activities. At the same time the group quickly developed very strong ties with the industry, which were strengthened through the involvement for many years by Cyril O'Connor and J.P. Franzidis in supervising Anglo American bursars from all universities during their vacation training. In 1996, the CMR joined the AMIRA P9 project as a major research provider, and this involvement and the strong collaboration with the Julius Kruttschnitt Mineral Research Centre (JKMRC) continues today. The project's strong focus on industrial problems was of great importance to the CMR's growing activities. It has focused mainly on comminution and flotation and was led initially in communition by Malcolm Powell (followed by Aubrey Mainza after Malcolm's departure for the JKMRC) and, in flotation, by Martin Harris (later to be joined by Jenni Sweet). During this period the flotation chemistry activity also grew significantly thanks to the enthusiastic leadership of Dee Bradshaw, who later followed Malcolm Powell to the JKMRC. This activity continues today to be very strong and has recently developed major collaborations with a number of international institutions such as BGRIMM in China. Dave Deglon (now Director of the CMR) began research in the 1990s on the use of CFD in the design and optimization of flotation cells. In this work he has established a strong collaboration with the Centre for Computational and Applied Mechanics at UCT and this field has become one of the CMR's strongest activities. The CMR was also fortunate to retain the services of former giants in the field of mineral processing, and people such as Peter Gaylard, Peter Harris, and Sandy Lambert have all made great contributions to its research activities

Many of the above initiatives were strengthened as a result of the support of the South African P9 sponsors who, through their collaborative structures, facilitated significant substantial funding from THRIP which contributed to growth in new areas of minerals processing research. One such example was the development of process mineralogy over the past six years by Dr Megan Becker. This activity will soon be strengthened by the acquisition of a state-of-the-art QemScan, thanks to a significant contribution by the NRF. In 2008 the CMR acquired a PEPT instrument from the UK thanks to the intervention of former UCT colleague Jan Cilliers, Head of the Royal School of Mines' Department of Earth Science and Engineering. The instrument is located at iThemba labs and has led to the development of another strong group within the CMR based in the Department of Physics under the leadership of Dr Indresan Govender (http://www.pept.uct.ac.za/). The PEPT research represents a very exciting new development within the CMR enabling

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validation of models of comminution and flotation processes and other areas such as visualizing flow patterns in airlift reactors. The research of the CMR is complemented by the work of the MPTech, the CMR's technological transfer arm, led by Jenni Sweet. This group is making a major contribution to the industry through on-site training of young metallurgical engineers, and also regularly consults to industry across the continent. MPTech is also responsible for training courses for operators on the use of JKSimMet.

Sue Harrison has continued to strengthen the research activities in bioleaching. Her Centre for Bioengineering Research (www.ceber.uct.ac.za/) also includes the activities of Jochen Petersen in hydrometallurgy, and they enjoy an excellent international reputation. Alison Lewis leads the Precipitation and Crystallization Unit (crystal.uct.ac.za/) and Harro von Blottnitz heads up the Environmental Process Engineering group (epse.uct.ac.za/), which is addressing some of the tougher environmental problems faced by the industry. J.P. Franzidis holds the SARChI Chair in Minerals Processing and in that position oversees the Minerals to Metals Research Initiative, in which he has successfully co-ordinated all of the minerals processing research activities at UCT and beyond by the development of a set of closely aligned research programmes (www.mineralstometals.uct.ac.za/). The CMR also acts as the host for the administration and management of the recently launched South African Minerals to Metals Research Institute (SAMMRI) (www.sammri.com).

In 1992 Francis Petersen was instrumental in establishing a strong minerals processing research activity at the former Cape Technikon. The focus of this research was in the broad area of hydrometallurgy (gold adsorption on activated carbon, IX resins and membranes, modelling, etc.) The work expanded over the years to include carbon, resins, and membrane-based research. In this regard he enjoyed strong support from companies/organizations such as the NRF, Mintek, Karbochem, CSIR, Sasol, and many others. After leaving, Francis has pursued a very successful career and is currently the Dean of Engineering and the Built Environment at UCT. Others who were closely involved with these early developments included Allan Nesbitt and Paul van der Plas. Further growth saw the commissioning of a pilot plant incorporating an inline pressure jig donated by Gekko systems of Australia and partly funded by the Chamber of Mines. The merger of the Cape Technikon and Peninsula Technikon to form CPUT resulted in the aligning of the two Departments, and this was facilitated by Allan Nesbitt from Cape Technikon and Tafi Madzimbamuto from Peninsula Technikon. With the arrival of Dan Ikhu-Omoregbe and Tunde Ojumu, research in bio- and hydrometallurgy strengthened even further and has become a major focus area (www.cput.ac.za/researchchemical).

Over and above these institutional developments, one of the strong features of the minerals processing activities in the Western Cape has been the excellent close collaboration that has always characterized its activities. One excellent example is the Western Cape Mineral Processing Facility (WCMPF), which was established in 1989 through generous funding from the Chamber of Mines. This was a collaborative educational initiative between the Department of Process Engineering at SU and the Chemical Engineering Departments at UCT and CPUT. Its primary objective was to facilitate the education and development of suitably qualified graduates for the mining and mineral processing industries. In addition, the WCMPF played an important role in promoting liaison and interaction between the institutions. Funding was used to hire contract technical staff to serve jointly the needs of all three institutions. In 2000, the role of supporting the WCMPF was transferred from the Chamber of Mines to the Minerals Education Trust Fund (METF).

Another example of close collaboration was the formation of the Western Cape Branch of the SAIMM in the early 1990s. The Branch Committee represents all three institutions and has oversight over activities such as an annual joint student day to showcase minerals processing as a career, and also organizes the annual Southern African Mineral Beneficiation and Metallurgy Conference. This Conference, which always takes place in early August each year, is now in its 29th year. Although the Conference continues to place importance on its original mission of providing a platform for postgraduate students to showcase their research, many papers are presented by delegates from industry, and among the usual 150-plus delegates are more and more international visitors (www.minproc-wcape.org.za).

In conclusion, hopefully these highlights of the growth and development in minerals processing in the Western Cape have shown that the three institutions are contributing significantly to ensuring the future supply of quality graduates to the industry. It has often been remarked that it is rather surprising to find such a strong minerals processing activity in a region that is relatively so far removed from the centre of the South African mining industry. This, however, merely illustrates that geographical distance does not inhibit doing quality research for the industry. The combined activities have always been characterized by very strong collaborations, a strong ethos of high-quality research, and a deep appreciation of the need to engage closely on a technical level with industry. The large numbers of postgraduates at the three institutions are all conscious of the need to appreciate the relevance of their projects to industry. It is interesting that, as was alluded to, during these past 30 years a number of those associated with the local institutions have emigrated to foreign countries and yet, notwithstanding this, new, exciting, and highly competent young staff have replaced them thus ensuring the long-term sustainability of these research activities. Today, building on this strong base, many new collaborations are developing globally in South America, China, and Eastern Europe as well as with traditional collaborations in the USA, Australia, and Western Europe. The philosophy of 'locally relevant but globally competitive' research will continue to characterize the minerals processing and extractive metallurgy research in the Western Cape universities. It is appropriate to close by expressing the sincere thanks of all three institutions to those companies, research organizations, and individuals who have made such major contributions to our research universities over the past 30 years and more, and have assisted us in creating an academic cluster that we believe represents a key national asset for the industry.

C.T. O'Connor

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### **Minerals Processing and Metallurgy research at UCT**

Research in the area of minerals processing and metallurgy at the University of Cape Town is hosted mainly in the Department of Chemical Engineering, although many collaborations exist in other engineering departments, physics and chemistry, and even the Graduate School of Business. Fundamental research in these areas is conducted primarily through some 100 postgraduate students at the MSc and PhD level, both resident at UCT and industry-based.

Within the Department, minerals processing and metallurgy-related research is carried out in four main research groupings – the Centre for Minerals Research (CMR), the Centre for Bioprocess Engineering Research (CeBER), the Crystallisation and Precipitation Research Unit (CPU), and the Minerals to Metals Initiative (MtM). The latter is not a standalone research entity, but rather a 'virtual' centre that fosters research through collaboration between various research groups in the Department and beyond.

In all our research our primary aim is to build capacity and generate knowledge for the minerals industry through the training of postgraduate students. We see our students as an integral part of who we are, what we do, and what we have achieved. Many of these students go on to take leadership positions in industry, both in South Africa and internationally. Our research output is highly rated through a large number of publications in leading international journals, and a significant portion of our researchers are NRF rated.

#### Comminution and flotation research

The CMR is a well-established centre for many aspects of research around the processes of comminution, classification, and flotation, arguably the most important unit operations in mineral beneficiation. CMR carries out research at both laboratory and plant scale, and through its MPTech division carries out confidential projects for a wide range of companies. Developing robust predictive models for describing the performance of industrial flotation and comminution units and circuits is an important aspect of the research. The Western Cape PEPT facility at iThemba Labs offers an exciting new research area for informing models of particle movement in flotation cells and tumbling mills.

### Leaching hydrometallurgy

Aqueous processing of mineral resources is becoming increasingly attractive due to energy and safety considerations compared with the conventional minerals beneficiation flow sheets involving pyrometallurgy. Leaching is the primary step in hydrometallurgy, and, beyond the historic focus on bioleaching, increasingly more research at UCT is focussed on leaching using non-biological media, such as ammonia, chloride, and cyanide in various reactor configurations, particularly heaps. A key focus is on selecting and optimizing reagents and reactor configurations for a specific application on the basis of sound principles of chemistry, engineering, and process economics.

#### Minerals bio-processing

One of the main research areas in CeBER is bioleaching, a

process in which microbes are used as biocatalysts to convert metal compounds into their soluble forms. This leaching process is an economical alternative method for the recovery of metals such as copper, nickel, zinc, and gold from lowgrade ores and secondary resources, with low investment and operating costs. We are particularly interested in understanding the sub-processes within heap bioleaching. Moreover, the same scientific understanding informs efforts to minimize acid rock drainage (ARD).

#### Process mineralogy

Process mineralogy is a rapidly expanding area of interest, creating significantly improved understanding of the behaviour and interactions of particular mineral phases in mineral processing and in leaching processes. This is greatly aided through access to state-of-the-art technology, such as SEM, QEMSCAN, MLA, X-ray tomography, electron microprobes etc. within the Western Cape.

#### Precipitation and crystallisation research

The main aim of CPU is to advance existing fundamental knowledge in the fields of crystallization and precipitation, especially related to the South African and international mineral processing and extractive metallurgy industries. The unit focuses on two main areas of research, namely the optimization of precipitation in hydrometallurgical processes, especially on mixed sulphides, and the development of innovative technologies for mining wastewater treatment, primarily eutectic freeze crystallization.

#### Minerals to Metals Initiative

The MtM Initiative, under the SARChI Chair in Minerals Beneficiation, is a multi-disciplinary grouping that carries out cutting-edge research, in which projects with a focus on some key areas of concern in the minerals industry – energy, water, benign wastes, and low-grade ore bodies – are conducted, often as a collaboration between the different research groupings listed above. The initiative is a virtual centre in that it draws in expertise from various engineering disciplines, geology, physics, business sciences, etc. The aim is to produce graduates with a broader view on challenges facing the industry.

J. Petersen

### Mineral processing research at Stellenbosch University

The Stellenbosch University Mineral Processing Research Group is based at the Department of Process Engineering. The aim of the group is to continue to deliver excellent undergraduate and postgraduate students, and to produce high-quality research outputs on industrially relevant topics. The research activities of the group focus on process modelling and process development in the areas of physical processing, pyrometallurgy, and hydrometallurgy. The majority of the projects undertaken by the Mineral Processing Group are industrially relevant and sponsored, and range from fundamental studies to applied process development.

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Research into physical processing of ores focuses on understanding new technologies that offer improved liberation of valuable minerals at reduced energy consumption. Computational fluid dynamics (CFD) is being used to model, understand, and improve a number of unit operations. Current projects include analysis of solid-liquidgas interactions in flotation vessels, the prediction of the effect of gas dispersion parameters and mixing on column flotation, the development of a CFD-based hydrocyclone classification model, and CFD modelling of a mixer for solvent extraction. Bonded particle modelling, allied with fundamental property-based flotation models, is being used to simulate microwave treatment, confined bed crushing, and coarse particle flotation.

Pyrometallurgy forms the foundation of many metal extraction processes. Research in this area focuses on modelling, optimization, and control of pyrometallurgical processes. CFD plays a key role in this, while fundamental high-temperature thermochemical studies complement the work, which is important for understanding furnace and ladle operation. The metallurgical phenomena inside furnaces are studied using a combination of cold physical models, miniature high-temperature models, computer models, and empirical models based on industrial process data. Examples of pyrometallurgical projects include the measurement of surface tension of molten matte phases, studying the effect of iron end-point composition on matte mineralogy during Peirce-Smith converting, and development of a roasting and smelting process for the removal of contaminants from a precious metal refinery feed.

Hydrometallurgical processing offers the opportunity to eliminate energy-intensive smelting operations, and such approaches are particularly attractive for treating lower grade ore bodies. Studies on leaching and carrier phase extraction methods are a significant part of the development, modelling, and optimization of new, low-energy hydrometallurgical processes for the recovery of both precious and base metals. The various leaching operations involved in the extraction of platinum group metals are being investigated in both fundamental and applied modelling and experimental studies. At the same time, development of new industrial hydrometallurgical routes to process alternative sources and to improve product purity forms the basis for a number of research projects.

Currently, more than 20 postgraduate projects are being undertaken in the Mineral Processing Research Group. The facilities of the group include various analytical instrumentation, licences for software packages, laboratoryscale hydrometallurgical equipment such as atmospheric and pressure leaching vessels, bottle roll rigs, a mixer-settler unit, and ion exchange columns, as well as a pyrometallurgical facility equipped with three temperature-controlled tube furnaces, a bottom-loading furnace, muffle furnaces, an induction furnace, and a DC plasma arc furnace. The group collaborates with Aalto University in Finland, the University of Cape Town, Nelson Mandela Metropolitan University, the University of Johannesburg, and the Copperbelt University, amongst others.

C. Dorfling

#### Mineral processing at the Cape Peninsula University of Technology

The foray into mineral processing at CPUT dates back to when the institution was known as Cape and Peninsula Technikons, with the appointment of Professor Francis Petersen as a lecturer in 1992. He had previously worked as a Chamber of Mines technical officer based at the University of Stellenbosch, where his research was in carbon-in-pulp systems. Initially, the mineral processing activities were mainly for research and postgraduate purposes. With the appointment of Mr Allan Nesbitt, also a former Chamber of Mines technical officer at the University of Stellenbosch, an initiative was undertaken to have the Cape Technikon join the Western Cape Mineral Processing facility. This was a joint initiative between Stellenbosch and Cape Town Universities, funded by the Chamber of Mines to enhance the practical mineral processing training of undergraduates. The result was the appointment of Mr Paul van der Plas as permanent technical officer based at the Cape Technikon.

Two further initiatives sealed the Cape Technikon's permanent involvement with mineral processing. These were the setting up of a unit operations undergraduate subject, which featured mainly mineral processing unit operations, and the establishment of a gravity separation research unit. A pilot plant incorporating an inline pressure jig donated by Gekko systems of Australia and partly funded by the Chamber of Mines was constructed. The first full-time technologist employed to run the pilot plant was Mr. Wayne Breytenbach, who oversaw numerous research projects conducted for many industrial corporates both within South Africa and Australia.

The initial collaboration in harmonizing the curriculum of the Cape and Peninsula Technikon began in 2004, before the official merger activities even started, with Mr Allan Nesbitt from Cape Technikon and Mr Tafi Madzimbamuto from Peninsula Technikon adopting a harmonized syllabus for Chemical Plant Module A: Mineral Processing Technology. In 2005 the Cape and Peninsula Technikons merged and mineral processing developed further. In 2010, under the stewardship of Professor Dan Ikhu-Omoregbe, an elective, Unit Operations of Hydrometallurgy, was introduced at the Bachelor of Technology level. Also, research in the areas of bio- and hydro- metallurgy began at CPUT with the appointment of Associate Professor Tunde Ojumu in January 2009. Research effort in bio- and hydrometallurgy is focused on providing understanding of the sub-processes of bioleaching, especially biooxidation of ferrous ion in both agitated and column systems, with the aim of making a distinction between the kinetics in these systems as they are applicable to tank and heap bioleaching situations respectively.

Т. Ојити

The Journal of The Southern African Institute of Mining and Metallurgy