The transfer of knowledge produced by the DEEPMINE Research Programme: A critical evaluation

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Synopsis

The DEEPMINE Collaborative Research Programme was established to create the technological and human resources platform that would make it possible to mine gold safely and profitably at depths of 3 to 5 km. The DEEPMINE Programme has four goals: to acquire knowledge of and develop appropriate technology for new ultra-deep level mines, to stimulate education and training, to establish a culture of innovation, and to encourage rapid technology transfer and implementation. The research programme was launched in July 1998 and will be completed in March 2002, with the final year focusing on the transfer of knowledge to the industrial partners. DEEPMINE represents a new model for conducting mining research: it is driven by industry needs; emphasizes collaboration between industrial partners, research organizations and tertiary education institutions; and has a novel joint-funding mechanism. DEEPMINE has employed a range of vehicles to transfer knowledge to its industrial partners. Novel aspects include: (a) electronic publication of Summary Reports and Guideline Handbooks that seek to consolidate the huge body of knowledge comprehensively and concisely, (b) a series of DEEPMINE Schools designed to enable industry practitioners to apply the knowledge to their current work situation, and (c) Consultancy Reviews, where DEEPMINE specialists seek to apply knowledge to specific real problems on mines.

Introduction

The South African gold mining industry has experienced considerable upheaval during the past decade: the dollar gold price has declined by almost one-third, the R/$ rate has increased dramatically, the Mines Health & Safety Act of 1996 introduced new legislation, and large mining houses have been restructured to form focused gold mining companies. These changes inevitably affected the way in which mining research was conducted. Perhaps the most dramatic examples being:

- The demise of COMRO and the birth of CSIR Miningtek
- The establishment of the Safety in Mines Research Advisory Committee (SIMRAC), which focuses on research aimed to improve safety and health
- The establishment of a series of collaborative research programmes. DEEPMINE started in 1998, and was followed by COALTECH2020 and FutureMine, with several others (PlatMine, EnviroMine) currently in the planning stage. Each programme has built on the experience of its forerunners.

The DEEPMINE Programme seeks to develop expertise and technology to mine gold safely and profitably at ultra-depth (3 to 5 km). It has been estimated that perhaps as much as 40,000 tonnes of gold remains at ultra-depth, an amount similar to the total production of Witwatersrand basin mines during the last century. The great technical and human challenges of mining at these depths has led to unprecedented co-operation between mining companies, research institutions, universities, labour and government. In this paper we seek to crystallize the learning of DEEPMINE with regard to knowledge transfer.

DEEPMINE: A brief history

From conception to completion

It has been apparent for some time that a significant part of the future of gold mining in South Africa lies at depths greater than 3 km, and various companies and research organizations established their own initiatives to develop technology to mine at ultra-depth (e.g. Diering, 1997; Willis *et al*, 1997). The concept of a collaborative research programme was conceived by Dr Güner Gürtunca (CSIR Miningtek) in May 1996, developed with the assistance of Prof. Huw Phillips (University of the Witwatersrand), and presented to the Foundation for Research Development (now the National Research Foundation) and the South African Institute of Mining and

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Metallurgy. As a result, the symposium *Innovative Concepts for Viable Technologies in Ultra-deep Level Gold Mining* was held on 11 June 1996. The next significant step was the convening of the DEEPMINE Forum on 6 March 1997. All stakeholders in the gold mining industry were invited, and CSIR Miningtek and the University of the Witwatersrand presented a proposal to establish a collaborative research programme. It was decided to form a Steering Committee, initially chaired by Dr Howard Hume of the Chamber of Mines and later by Mr David Diering of AngloGold Ltd, to review the proposal and to formulate a research strategy.

The Steering Committee convened a workshop to identify possible research topics in August 1997. Altogether 208 research needs (or tasks) were identified and grouped in two scenarios, one being an extension of present technology or new technology which can be developed or brought on-stream within 5 years, and the second being future technology. The DEEPMINE Steering Committee appointed a working group to review the proposed topics and to obtain ratings from the mining companies for the proposed topics. A series of nine project planning workshops were then held to identify the objectives, outputs, milestones, cost and duration of each research task, and to rate its importance. The original 208 tasks were condensed into 145 tasks: 98 tasks were rated 'A', indicating that they are critical to ultra-deep mining; 44 tasks were rated 'B', indicating that they are very important but less critical; and 3 tasks were rated 'C', as they investigate issues that are important but are not stumbling blocks to ultra-deep mining. The task definitions and work plan are included in the DEEPMINE Business Plan (January 1998), which was presented to the DEEPMINE Forum on 17 February 1998, and interested parties were asked to confirm their participation and their financial commitment.

Three mining companies (AngloGold Ltd, Durban Roodepoort Deep Ltd, Gold Fields Ltd) and the Chamber of Mines confirmed their support of the DEEPMINE Programme, and the Programme Manager was appointed from April 1998. A meeting of nominees to the DEEPMINE Board was held on 16 April 1998, where the composition and responsibilities of the Board was discussed. The first chairman was elected, and a press conference and cocktail party was held to officially launch DEEPMINE.

The research work commenced in July 1998 and is scheduled to be completed in March 2002. It covers a wide range of disciplines, including industrial sociology, physiology and psychology, mining and mechanical engineering, and earth sciences. Over two hundred and fifty researchers have been involved in the Programme. While DEEPMINE's focus has been on mining at ultra-depth, many spin-offs will benefit mining at current depths. The scope of the Programme is summarized below.

- In the first year (July 1998 to March 1999), emphasis was placed on those technology elements considered critical to mining at ultra-depth viz. occupational health and safety, delineation and characterization of geological structures ahead of mining, mining layouts and methods, stope support, seismic management, refrigeration and ventilation, and access development and support. Forty-five tasks were started, of which nineteen were completed by the end of the research year. The budget was R15,5 million.
- During the second year, work continued on many of the tasks, while a new focus on the transport of men, material and rock was introduced. Twenty new tasks were started as part of the core Programme, as well as another three tasks that were part of a new Higher Education Institution (HEI) Development Scheme. While the research work carried out by the HEI Scheme must be relevant to DEEPMINE, the focus is on the development of competence rather than technology. The budget was R19,7 million.
- During the third year, the emphasis of twenty new tasks was on the integration of the research findings and the formulation of guidelines for the designers and operators of future ultra-deep mines. The HEI Scheme increased considerably and R1 million was allocated to it. The budget was R21 million.
- During the fourth and final year, the emphasis is on knowledge and technology transfer through activities such as knowledge transfer schools, consultancy reviews on mines operated by the industrial partners, and the commercialization of services and technologies. The budget was R9 million.

Management structures and processes

Management structures and processes are briefly described, as they play a significant role in the success of the programme.

Board

The Board is comprised of representatives of the industrial partners (AngloGold Ltd, Durban Roodepoort Deep Ltd, Gold Fields Ltd, Chamber of Mines) and other stakeholders in the deep-level gold mining industry (CSIR, National Union of Mineworkers, Mining Labour Caucus, Witwatersrand University, Department of Minerals and Energy, Department of Trade and Industry, National Research Foundation). The chief functions of the Board are to ensure that the Programme adheres to the guiding principles as set out in the Business Plan, approve the long-term research strategy, approve the annual research programme and budget, approve Technical Management Committee recommendations on the allocation of tasks to research agencies and universities, and monitor the research outputs and facilitate implementation. The Board meets quarterly. The first chairman was Mr Keith Spencer (Gold Fields Ltd), who was succeeded by Mr David Hodgson (AngloGold Ltd).

Technical Management Committee (TMC)

The TMC is the 'engine room' of the Programme. It is comprised of representatives of the industrial partners (AngloGold Ltd, Durban Roodepoort Deep Ltd, Gold Fields Ltd, and the Chamber of Mines), CSIR, Witwatersrand University and NUM. The chief functions of the TMC are to provide technical advice to the Board, assess priorities for research work, receive and evaluate tenders, and guide and review research work. The TMC has a regular monthly meeting. In addition, there have been numerous special meetings and workshops to formulate the work plan, adjudicate tenders, provide guidance to researchers, and evaluate progress. Mr David Diering (AngloGold Ltd) has been chairman for the duration of the programme.

Programme management

CSIR Miningtek personnel were seconded to manage DEEPMINE, and use was made of CSIR resources (office space and facilities, accounting and legal services, etc.). The Programme Manager's function is to implement Board and Technical Management Committee directives. Dr Ray Durrheim has been the Manager for the duration of the Programme. Mr Charles Sevume was appointed as Technical Assistant in 1999, and was succeeded by Mr Shiko Kebonte in 2001. Mrs Sue Kimberley provides secretarial and administrative support for DEEPMINE, COALTECH2020 and FutureMine Programmes.

Guiding principles

The DEEPMINE Programme has four goals: (i) to acquire knowledge of and develop appropriate technology for new ultra-deep level mines, (ii) to stimulate education and training, (iii) to establish a culture of innovation, and (iv) to encourage rapid technology transfer and implementation. A number of principles were developed by the Steering Committee to help DEEPMINE achieve these goals. The Guiding Principles contained in the Business Plan are summarized below, together with a description of how the principles were put into practise and a critical assessment of their relevance and the effectiveness of their implementation.

Research programme is driven by industry needs

The DEEPMINE Business Plan (1998) states:

...the programme must satisfy the needs of DEEPMINE's industrial partners and the content and direction of the programme should be guided by those partners who will be the primary users of the knowledge and technologies arising from the programme.

The industrial partners re-evaluated their participation in DEEPMINE annually. Consequently, sensitivity and responsiveness to industry needs was essential to ensure their continued support. The industrial partners drove the Programme through their involvement on the Board, TMC, progress reviews and report evaluations. Researchers had input into the process through their participation in the working groups where needs were discussed and tasks defined, and in their progress reports. The influence of industry is perhaps best illustrated by changes in the scope of work in response to changes in the external environment, findings of the research work, or the recognition of gaps in the original work plan. Of the original 98 A-rated tasks contained in the Business Plan, 24 were not carried out and 30 tasks were added. Furthermore, the scope of many tasks was modified.

Continuity and commitment by members of the Board, TMC, research teams and programme management was critical to maintaining a close alignment with industry needs. It was not always easy to achieve this.

- Interest in South African ultra-deep level mining waned owing to changes in the external environment (e.g. decrease in the dollar gold price, restructuring of the industry and companies, and a focus on shallow low-cost prospects outside South Africa). Because of these changes, one partner (Durban Roodepoort Deep) temporarily withdrew, and the active involvement of the Chamber of Mines diminished.
- Involvement in the DEEPMINE demanded a substantial commitment of time, particularly for TMC members who had to adjudicate research proposals, attend progress reviews, interact with researchers, and evaluate reports.
- During the four-year lifetime of the programme, there have been substantial staff changes brought about by transfers and reassignments, retrenchments, resignations and death.

Fortunately, a committed core group has remained involved with the programme from beginning to end.

Collaboration

The DEEPMINE Business Plan (1998) states:

Collaboration between organizations is to be encouraged in submitting research proposals and carrying out the research programme. Even when research tasks have been awarded to a specific organization, that organization should seek an appropriate degree of collaboration.

Industrial partners

The sharing of information by mining companies was essential to avoid wasting resources duplicating work and to start building from as high a knowledge base as possible. As the Programme proceeded and understanding and trust developed between committee members, there was unprecedented sharing of information and know-how. This was facilitated by industry trends, which saw significant restructuring and rationalization within the industry (taking down the farm fences) during this time. This was not without its difficulties, as companies were not prepared to share information that was sensitive (e.g. grades of orebodies) or was perceived to give them a competitive advantage. However, competitive advantage was generally seen to lie in the ability of a company to implement knowledge or technology, rather than merely in its ownership, and the position was taken that information would be kept confidential only in exceptional cases.

Researchers and research organizations (CSIR, consultants, academics, etc.)

Collaboration between research suppliers was seen as essential for the following reasons:

- To ensure that the best brains were used to solve the problems
- To avoid groupthink, especially on topics where different individuals or organizations hold differing views
- To develop competence at CSIR, Universities and Technikons and
- To avoid creating a monopoly in providing products and services developed by DEEPMINE.

The push for collaboration went counter to the desire of organizations to maximize their 'slice of the cake' and to 'protect their turf' by preventing competitors increasing their competence and gaining exposure. The matter was further complicated by CSIR Miningtek being both a sponsor of DEEPMINE and a supplier of research. This was not the only

potential conflict of interests, as there were instances where mining companies and TMC members had close ties with consultants.

Processes and structures had to be developed to facilitate collaboration. In the first year of the programme, invitations to submit proposals were sent to all credible suppliers of research identified by the working groups. Despite the invitation clearly stating that DEEPMINE desired meaningful collaboration, in most cases this was not realized, and the TMC had to intervene to achieve the desired levels of collaboration. Subsequently DEEPMINE adopted a 'competence-based invited tender process', whereby clear directives were given to the selected research suppliers regarding the allocation of work to different suppliers, and CSIR's special role as a national competence base and integrator of research was recognized. In many cases the relationships between collaborators was excellent and a high degree of cooperation was achieved. In other cases, however, the relationship between suppliers was strained with limited engagement and exchange of ideas, while in a few instances the relationship dissolved in acrimonious disputes. Collaboration between research suppliers was only achieved through:

- Forceful insistence by the TMC
- TMC members having a good knowledge of credible suppliers of research. Regular features on DEEPMINE in the mining press alerted other technology providers to the Programme, and gave them the opportunity to bring their competence to the attention of DEEPMINE
- Acknowledgement and discussion of possible conflicts of interest
- Constant monitoring of the research work by the TMC and programme manager, and intervention where necessary
- Willingness on the part of research suppliers to form relationships with a network of associates, some of whom may simultaneously be competitors.

Government and employee organizations

The National Research Foundation (NRF) is the custodian and administrator of THRIP funds, and actively participated on the Board and TMC, vigorously urging DEEPMINE to expand its range of contacts with higher education institutions. The involvement of labour was desirable so that views and input of employees on the efforts to develop technology and competence could be obtained at an early stage. Similarly, it was believed to be essential that the Department of Minerals & Energy be informed of developments in technology and practise so that mining inspectors are able to monitor and regulate their deployment. DEEPMINE made the commitment that no development relevant to health and safety would be withheld from the broader mining industry, and labour and government representatives on the TMC and Board had full access to all progress reviews, research reports and schools. However, because of a lack of capacity, the involvement of labour organizations and the mining inspectorate was limited. Nevertheless, these organizations played a vital role in lobbying government for funding for mining-related research, and in addressing some of the issues related to THRIP funding (see the next two sections that follow).

Promotion of centres of tertiary learning

The DEEPMINE Business Plan (1998) states:

- *The Programme must encourage the development of appropriate numbers of suitably competent ultra-deep mining researchers and students in line with the research and technology needs*
- *The Programme must result in an adequate supply of practising mining engineers and other required disciplines with a high level of competence in ultra-deep level mining*
- *The Programme should involve a broad spectrum of researchers and students to increase their awareness of the challenges of ultra-deep level mining whilst recognizing that they may pursue careers in other fields.*

Furthermore, the involvement of students at higher education institutions (HEIs) in the DEEPMINE Programme is a prerequisite to procure funds from the Technology and Human Resources Programme (THRIP).

In the first year of the programme, involvement of academics and postgraduate students proved to be problematic. Research suppliers did not include them in their teams to the desired extent, either through ignorance of the expertise residing at HEIs, or a desire to not dilute their share of the contract. It was also difficult for researchers at HEIs to submit proposals as candidate postgraduate students were (and are) scarce and could not easily be recruited without secured funds, and DEEPMINE was reluctant to award contracts to teams that were inadequately staffed. To overcome this 'chicken and egg' situation, a HEI Scheme was introduced in February 1999. The Board decided to reserve R1 million to proactively facilitate the involvement of universities and technikons in DEEPMINE. Guidelines for the Scheme were drafted, and in March 1999, invitations were sent to staff members identified by the TMC and NRF as having the potential to contribute to DEEPMINE.

The University of the Witwatersrand accepted responsibility for coordinating the scheme. However, this proved to be problematic, as Witwatersrand University did not want to be in a position where it had to vet applications by other institutions. Witwatersrand University was prepared to invite other institutions to work with it in areas where it had expertise, but felt that there should be opportunities for other institutions to lead research projects in other fields. Furthermore, there was some delay in the appointment of a senior academic to coordinate the Scheme and solicit participation by other HEIs. Consequently the programme manager assumed responsibility for coordinating the Scheme. The first task proposals were approved by the TMC in December 1999, and in year 3 of the Programme (2000/2001) over R1 million was allocated to tasks supported by the Scheme.

Apart from conducting research, students at HEIs were involved in DEEPMINE activities in several other ways. About 70 students from the final year mining engineering classes at Witwatersrand University and Technikon attended the DEEPMINE Colloquiums in 2000 and 2001. The first Postgraduate Colloquium was held at Witwatersrand University in November 2000 and was attended by about forty people, including researchers from Natal and Potchefstroom University. In 2001 the Postgraduate Colloquium was held at Moab Khotsong mine and included

an underground visit, which was of special interest as many of the students had only had very limited experience to the mining environment. The DEEPMINE model of an ultra-deep orebody was used as the basis for the 4th-year mine design project at Witwatersrand University. The leaders of the two teams judged most innovative by the course lecturers were invited to make presentations to the TMC and other industry experts, and DEEPMINE awarded a prize to the best team.

While DEEPMINE succeeded in assisting students to gain industrial experience and obtain postgraduate degrees, a far greater level of involvement with the core research teams is desirable.

Joint funding model

The Programme was based on a funding model whereby CSIR undertook to make use of part of its parliamentary grant to match industry contributions rand-for-rand, subject to an agreed maximum. Furthermore, application would be made to the Technology and Human Resources for Industry Programme (THRIP), which would potentially also match the industry contributions rand-for-rand. This model meant that should only two companies participate in the Programme and contribute equal amounts, each would get a six-fold leverage on their investment, i.e. for each R1 contributed, R6 worth of research would be carried out. Should there be greater participation, the leverage would increase accordingly. While this mechanism was highly attractive and was largely realized, several issues emerged during the duration of the Programme.

- It was necessary to develop ways of determining the financial contributions of industrial partners, especially as the size of the companies differed substantially, and companies, ability to contribute was affected by performance and strategy. No magic formula was found, and financial contributions were the subject of considerable 'behind the scenes' discussion.
- THRIP's substantial financial contribution to the Programme, which was in fact considerably greater than that of any individual industrial partner, is gratefully recognized. However, several issues concerning THRIP funding arose during the course of the Programme. Many of the problems have been addressed, but we report them here to alert potential participants in similar programmes to the types of pitfalls that may be encountered.
  - There were several changes to THRIP rules and criteria during the course of the Programme. The most significant were (i) the disqualification of CSIR manpower costs as 'THRIPable' costs, and (ii) a preference for research that benefits the manufacturing sector rather than other economic sectors such as mining.
  - Serious delays in the adjudication of proposals were experienced. This made it extremely difficult to manage the research work according to the plan submitted to THRIP, and to recruit and retain students. THRIP sought to overcome this by advancing the submission date, which had the effect that it was necessary to submit a plan of work for the next year long before the current year's activities were completed.
  - An online submission and reporting system was introduced. Severe teething problems were experienced, making these activities exceptionally onerous.

Knowledge transfer: a critical evaluation

DEEPMINE has employed a range of measures to transfer knowledge to its industrial partners and other participants in the Programme, and stakeholders in the gold mining industry. The medium and message depended on the objective of each communication, but whether it was to lobby for funds or to recruit research students, all had a role to play in achieving the goals of the Programme.

Communiqué

A brief quarterly information sheet was produced to keep Board members up-to-date with progress and developments in the intervals between Board meetings. While the communiqué certainly fulfilled a valuable function, it would be desirable to extend circulation to all participants, including all researchers and practitioners.

Colloquium

The findings of the Programme were presented annually at a one-day colloquium held during July in Carletonville. The colloquia were open to the staff of all organizations involved in the DEEPMINE Programme, and as many as 300 persons from industry, labour, government, research organizations and tertiary education attended. However, many of the attendees left at lunchtime, and missed some of the most relevant presentations.

Public lectures and other invited presentations

The programme manager played the role of 'missionary', giving presentations on DEEPMINE to many different groups, ranging from the executive committees of participating companies and organizations, in-house technology forums, government ministers and senior civil servants, postgraduate seminars at universities, and meetings of scientific and technical associations such as the S.A. Institute of Mining and Metallurgy.

Symposia and conferences

DEEPMINE researchers presented several dozen papers and posters at symposia and conferences during the course of the Programme. In order to protect the interests of the DEEPMINE sponsors, papers were first reviewed by the TMC to ensure that no information that was sensitive or had clear commercial value was divulged. The presentation of papers at scientific meetings was encouraged primarily to enable researchers to network with colleagues, rather than as a means of transferring DEEPMINE knowledge.

Magazines and newspapers

The activities of DEEPMINE were publicized by giving interviews and press releases to newspapers and magazines. The main purpose of these communications was to ensure that sponsors such as THRIP obtained public recognition for

their contribution, and to attract the interest of developers and suppliers of technology world-wide who may not be known to the TMC.

Research reports

Research reports are the primary product of DEEPMINE. To facilitate dissemination of research findings, each company or organization belonging to DEEPMINE receives a bound copy of all final reports, as well as an electronic copy on CD, and also is given access to the 'members only' area of the web site where reports can be viewed and downloaded. DEEPMINE will produce over 100 research reports. In order to help the practitioner access and digest this vast amount of information and to understand the complex interaction between the various systems in a deep-level mine, a series of seven Summary Reports were written, encompassing the entire research programme. The Summary Reports are aimed at researchers and technology managers. Each Summary Report;

- Gives a brief history of the work, including the motivation for the research work, descriptions of blind alleys that were encountered and negative results that were obtained
- Reviews all findings and recommendations
- Identifies remaining gaps in knowledge and technology, and provides recommendations for further research work
- Highlights the links between the various tasks and projects, and
- Highlights those findings relevant to current mining operations.

Furthermore, a series of seven Guideline Handbooks that provide a comprehensive guide to the design and operation of ultra-deep mines were written. The Guideline Handbooks are aimed at industry practitioners. Each Guideline Handbook;

- Provides a systematic guide to the 'does and don'ts' of ultra-deep mining
- Make recommendations on best practice taking different geotechnical areas into account if appropriate
- Highlights the interactions between technologies, and
- Is illustrated with worked examples.

The Summary Reports and Guideline Handbooks are brief and concise. The CD versions use hyperlinks to enable the reader to instantly access the source documents, which may be the original DEEPMINE report, or even SIMRAC reports, research papers and theses, where digital versions of these documents are available.

Web sites

A DEEPMINE web site was constructed at http://deepmine.csir.co.za. The site has a public area giving general information about the objectives and findings of the Programme that has attracted several queries from researchers and suppliers to the mining industry. The most important part, however, is a password-protected area accessible only to DEEPMINE members where items such as the minutes of meetings and the full text of research reports are published. Technology and capacity advanced significantly during the duration of the Programme, and there is huge scope to exploit the power of the internet to manage large research programmes and disseminate findings. To facilitate access, DEEPMINE reports are also being published on the intrawebs of DEEPMINE members.

DEEPMINE Schools

DEEPMINE Schools are the primary means whereby the knowledge gained through the Programme is transferred to the industrial partners so that the knowledge may be implemented, where appropriate, in current mining operations. A series of nine Schools encompassing the entire Programme have been offered. The duration of the Schools ranged from two to five days, depending on the volume of material. Most Schools included two underground visits, either to sites where things are 'being done right', or where new systems or technology is being implemented. The Schools were open to the staff of all organizations involved in the DEEPMINE Programme, including industry, labour, government, research organizations and tertiary education. To improve accessibility to mine employees the Schools were held at Gold Fields Training Centre at Kloof Gold Mine. Altogether 200 persons, mostly employees of mining companies, attended the Schools. This was far fewer than anticipated. Many more enrolled for the Schools, but dropped out at the last minute. This is attributed to the 'tyranny of the urgent' i.e. great work pressure and a limited appreciation of the importance of lifetime learning.

Comprehensive sets of course notes were prepared, carefully cross-referenced to DEEPMINE reports and other source documents. It is intended that this material will be used for in-house training, for teaching at universities and technikons, and for continuing education courses that may be accredited by the South African Mines Qualification Authority.

Consultancy Reviews

The final vehicle for transferring knowledge are Consultancy Reviews, which are in-depth investigations of an entire mine, part of a mine, or any process, system or practice (e.g. mine design, ventilation, stope support, powering) by a team of DEEPMINE experts. The costs of Consultancy Reviews are covered by the DEEPMINE budget. A Consultancy Review could:

- Review compliance with DEEPMINE guidelines
- Provide advice regarding best practice, or
- Identify opportunities to apply the knowledge gained and technology developed by DEEPMINE.

A confidential report will be delivered to mine management containing the findings of the Review. The emphasis is on practical recommendations supported by cost-benefit analyses. The Reviews are currently in progress, so we are unable to comment on their effectiveness.

Conclusions

Knowledge transfer is not simply the final link of a chain where the producer (the researcher) passes on the product (say a report or design) to the consumer (the mining industry). Rather, it is a two-way process that supports the entire research, development and implementation enterprise. The DEEPMINE model attempts to address the entire chain.

Firstly, there must be thirst for the knowledge! DEEPMINE sought to ensure that the knowledge it produced is relevant to the needs of the mining industry by creating structures and processes that ensured continuous industry involvement. This requires champions with vision and perseverance. DEEPMINE seemed to get this right much of the time, though interest in the Programme waned considerably as the gold price fell and it became evident that ultra-deep mining was not likely to take place in the short-term.

Secondly, the knowledge produced must be of top quality. DEEPMINE demanded high levels of collaboration to ensure that the best brains and resources were applied to the problem. This demanded a change in the culture of researchers and research organizations—a commitment to satisfy the customer, and a willingness to form associations with competitors. Here DEEPMINE achieved a qualified success: there were many examples where collaborative teams worked well together, and a few cases that ended in divorce. Continuous monitoring of progress and deliverables was also necessary to ensure quality. This placed considerable demands on the members of the Technical Management Committee, in particular. Some research work produced significant new insights or resolved contentious issues and the reports were regarded as 'milestones', most reports were satisfactory, and a few were failures.

Thirdly, the means to transfer the knowledge must be appropriate and effective. DEEPMINE employed a range of vehicles. Aspects that are novel to the South African mining industry include:

- **Summary Reports** and **Guideline Handbooks** that seek to consolidate the huge body of knowledge comprehensively and concisely, highlighting the interactions between the different systems that comprise a deep-level mine. The publication of these documents on CD, making use of technology that enables cross-linking to related topics and down-linking to source documents, was particularly effective
- A series of **DEEPMINE Schools** designed to enable industry practitioners to apply the knowledge to their current work situation. The attendance at the Schools was, unfortunately, disappointing
- **Consultancy Reviews**, where DEEPMINE specialists sought to apply knowledge to specific real problems on mines. The process is under way, so we cannot comment on its success yet.

The success of knowledge transfer is difficult to quantify, and it is probably premature to attempt to do this as the DEEPMINE Programme will be completed in March 2002 and knowledge transfer has only been a focus during the final year. Furthermore, the knowledge will only be fully implemented if the gold price rises to levels where the mining of ultra-deep resources becomes attractive, although much is applicable to current deep-level mining operations. The gap between the laboratory and the mine is wide, and DEEPMINE has attempted to find ways to improve the transfer of knowledge from researchers to practitioners. In hindsight, it is evident that we could have done things better, yet we believe that DEEPMINE has created models and set benchmarks for knowledge transfer that succeeding collaborative research programmes can build upon.

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Literally hundreds of people, far too many to list here, have participated in the DEEPMINE Programme. We are grateful for their contribution. In particular, we would like to acknowledge Mr Johan Klokow (Gold Fields), Mr Dick Kruger (COM) and Dr Güner Gürtunca (CSIR) who, together with the authors, have served on the TMC throughout the DEEPMINE Programme.

References

DIERING, D.H. Ultra-deep level mining—future requirements, *Journal of SAIMM*, vol. 97, 1997. pp. 249–255.

WILLIS, R.P.H., JAGER, A.J., MARX, W., JOHNSON, R.A., SCHWEITZER, J.K., KRAMERS, C.P., and MACNULTY, N.M. Mining R&D Strategy—Beyond 3000. *CSIR Report* Y1675. 1997.

SAIMM Colloquium: Knowledge and Technology Transfer, 26 February 2002, Mintek, Randburg. ◆

Eastern Cape take quiz in nailbiting finish*

A team made up of three learners (Douglas Hobson: Union High School, Graaff Reinet, Pierre Rossouw: Hoërskool Brandwag, Uitenhage, and Luyuvo Maloni, Moses Madiba High School, Kirkwood) won the National Final of Mintek's Minquiz schools' science competition at Mintek on 10 May 2002.

The hotly contested competition—there was only one point between first and second and three points between second and third, after five tie-breaker questions—had the Gauteng South team of Simon Spicer (St John's College), Johan van Staden (Hoërskool Florida) and William Tefo (St Barnabas College) in second place, with a team comprised of Tyrone Negus (Kloof High School), Wynand Louw (Kloof High School), and Janice Coeries (Domino Servite) in third place.

The winners in the first team qualify for bursaries in minerals-related careers from sponsors Anglogold, Xstrata, and Sasol, and the runners-up scored with generous cash prizes for their schools. Co-sponsors of Minquiz 2002 are Anglo Platinum, Multotec, Afrox, and Algorax.

Minquiz, which is Mintek's premier event for the promotion of careers in science, engineering and technology to high school learners, especially in the minerals field, has been running for 15 years, and in 1990 a televised version of the quiz (the *Gee Whiz* quiz) included South Africa's first astronaut Mark Shuttleworth in its winning team from Bishops. ◆

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