Planning for value in the mining value chain

by A. Vorster*

Mine planning to deliver value—a complex problem

The objective with mine planning is to consistently deliver production conforming to quality and quantity requirements throughout the life of the mine. The complexity of the operational context of the modern mine extends far beyond the actual production actions and there is a need to find ways of analysing and managing this extended environment.

A well-established approach to handling complex situations rely on the creation of representative models that use classification and visualization strategies.

An example of the use of a classification scheme is the periodic table of the elements. All physical matter can be expressed as combinations of basic elements. Not only is the periodic table useful in classifying and identifying matter but it can also be used for the prediction of the properties of unknown matter and compositions of elements.

An example of visualization techniques are the physical mine models that are often used to determine the design parameters for new orepasses and other physical structures that have to interoperate deep below the surface. This approach is rapidly being augmented, and replaced, by computer generated three-dimensional graphics.

The use of value chains, as proposed by Michael Porter[1] and widely adopted as both a classification technique and visualization scheme, provides high level functional models for use during the analytical phase.

This paper examines the generation of solutions, and the estimation of the value presented by a solution, using the Zachman framework as an aid to generating representative models that are employed to manage the complexity of the solution domain.

The use of value chains

The value chain concept states that it is possible to derive competitive advantage by arranging value adding activities in a sequential chain in order to satisfy the requirements of a customer. Both the value adding activities and the linking of these activities may be sources of competitive advantage.

According to the value chain concept the enterprise may be modelled as a range of primary activities that are responsible for the generation of value and a range of supporting activities that do not directly generate value but support the value generating activities.

The margin obtained is derived by examining the primary and supporting activities involved in the establishment of each value chain and tuning the activities in order to derive the maximum value chain throughput.

Looking at Figure 1 it is evident that the Porter value chain concept may be used as both a classification and visualization technique to assist in the modelling of the enterprise activities.

The construction of a mining specific value chain

During the past year personnel from Graphic Mining Solutions International and clients in the mining business have been actively involved in the creation of a high level process model that depicts the business functions of the mining process as depicted in Figure 2. The arrow in Figure 2 denotes the direction of value accrual.

Each of the value chain steps consists of a transformation that transforms the inputs into value added outputs as given in Figure 3.

Mapping the mining value chain to the Porter value chain model

Figure 4 depicts the mapping of the generic mining value chain to the Porter model. Note that the emphasis is on the mining activities and thus the outbound and marketing functions are not seen to have the same importance as would be the case in a manufacturing enterprise. In normal mining operations these functions are often performed by third parties or form a part of specialized services that could be considered to fall in the category of supporting services as depicted in the Porter model.

It has to be borne in mind that the high level of abstraction inherent in the simple depiction of the mining value chain as in Figure 4 might not be adequate to model real situations. In these instances it is required to establish a more representative model in order to understand the situation and the governing constraint set.

Generating representative models

The objective with mine planning is to consistently deliver production conforming to quality and quantity requirements throughout the life of the mine by the establishment of an environment conducive to the performance of the mining operations.

Some of the aspects that have to be planned for include:

- ➤ Ventilation
- ➤ Heat
- ➤ Humidity
- ➤ Dust and contaminants
- ➤ Radiation
- ➤ Industrial water

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		Primary activities					**Margin**
		Inbound logistics	Operations	Outbound logistics	Marketing and sales	Service	
Supporting activities	Enterprise infrastructure Human resources Procurement Financial management Research and development Risk management Information systems						

Figure 1—The Porter value chain concept

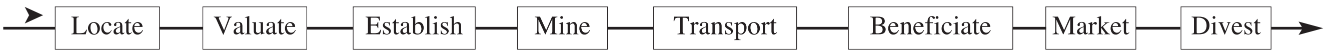


Figure 2—The generic mining value chain showing direction of value accrual

Transformation	Definition	Input	Output
Locate	The determination of the presence of a deposit	Suspected mineral resource deposit	Mineral resource estimate
Valuate	The determination of the . profitability of a project	Mineral resource estimate	Bankable feasibility (Go – No Go decision)
Establish	The execution of the mine plan	Bankable feasibility (Go – No Go decision)	Exposed mineral resource
Mine	The removal of mineral resources	Exposed mineral resource	Contained and classified broken rock
Transport	The movement of classified broken rock from source to destination	Contained and classified broken rock	Stockpiled tonnage at grade
Beneficiate	The extraction of saleable products and the disposal of residue	Stockpiled tonnage at grade	Saleable products
Market	The maximization of profit	Saleable products	Revenue and profit
Divest	The curtailment of operations	Revenue and profit	New economic circumstances

Figure 3—The mining value chain functional transformations

		Primary activities									Margin
	Michael Porter model	Inbound logistics			Operations			Outbound logistics	Marketing and sales	Service	Margin
	Mining value chain	Locate	Valuate	Establish	Mine	Transport	Beneficiate	Marketing		Divest	
Supporting activities	Mineral resource management Financial management Procurement / logistics Asset / maintenance management Research and development Human resource management Risk management Information systems										

Figure 4—Mapping the mining value chain to the Porter value chain concept

Potable water
- ➤ Electric power
- ➤ Illumination
- ➤ Machines
- ➤ Materials
- ➤ Labour
- ➤ Transport
- ➤ Production
- ➤ Extraction methodology.

All of these aspects are subject to constraints. These constraints may be imposed by the hard factors like geology, grade, the environment, technology, finances, legislation, safety or several softer factors like morale, industrial relations, market sentiment and investor perceptions. It is not uncommon to find that there are several levels of relationships between the aspects influencing production and the constraints that they are subject to. In many instances these relationships are non-linear and inherently interconnected. This does not allow a piecemeal approach and could require an iterative approach where several aspects are considered and successively altered in order to try and establish a solution.

Problems are normally managed by an approach that identifies the problem, sets a goal that will eliminate the problem, establishing a plan to achieve the goal and then executing this plan to achieve a solution. The use of an iterative process to achieve this is depicted in Figure 5.

The value delivered by a plan may be expressed as the inverse of the residual problem after a completed iteration. The residual problem is denoted by the intercept of the solution locus with the problem axis. The value delivered by the execution of the plan may be expressed as the inverse of this intercept. This provides a relative measurement of the value of the plan by simply referring to the residual problem. It is important to understand that the solution domain should be a complete model of the governing constraint set.

The trajectory of the solution *locus* is determined by the optimal exploitation of the governing constraint set. This requires that the problem, goal, solution and execution will be expressed and executed within the bounds of the governing constraint set. The constraint set could be depicted as a multi-dimensional hypercube superimposed on the domain of Figure 5. Each dimension of the hypercube addresses a particular constraint. The complexity of the planning situation has already been touched upon and we could find that the computational requirements to find a solution could rise exponentially with each new dimension of the bounding constraint set. This could lead to a non-deterministic polynomial, or NP-complete[2], situation that is not feasible to solve with traditional computational techniques.

The solution *locus* of the ideal plan will of course only make one excursion and intercept the problem axis at the zero point. Thus the value of the ideal plan will be infinite.

The Zachman framework[3,4] as a classification scheme

The use of the Zachman framework as a classification scheme was first published in 1987. The framework consists of the six basic interrogatives that are arranged in successive levels of increasing detail, or decreasing abstraction, as depicted in Figure 6.

The columns of the Zachman framework have no set order in contrast to the order of the rows that depict the different levels of abstraction. It is important to bear in mind that the framework could be seen as a cylinder with the last column, Why, meeting up with the first column, What.

Each row presents a complete model for a particular level of abstraction. The model is constructed by answering all six interrogatives. These models provide a concise and complete description of the situation at that particular level of abstraction and the governing constraint set.

Note that each downward transition presents a decision point in as far as the evaluation of the governing constraint set is concerned. The first rule is that each successive lower row inherits the current constraint set of the preceding higher row. The second rule is that the current row could have an additional constraint set particular to this row. The row specific constraint set may include constraints that were not considered at the next higher row. These constraints will form the operative constraint set and invalidate those aspects

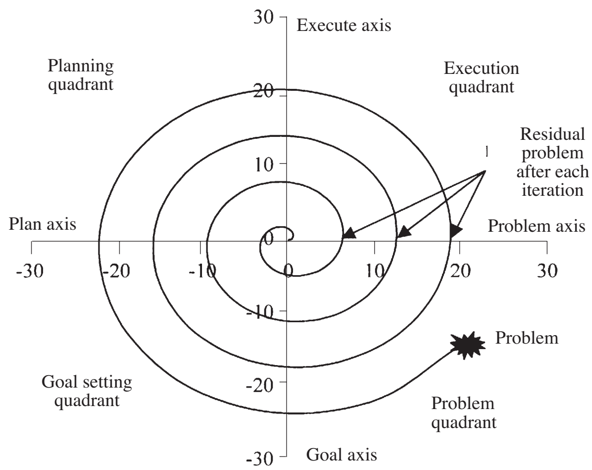


Figure 5—Depiction of the trajectory of the solution locus for an iterative planning process

	What (things)	**How** (processes)	**Where** (places)	**Who** (people)	**When** (time)	**Why** (motivation)
Planner (contextual) Owner (conceptual) Designer (logical) Builder (physical) Sub-contractor (out of context) Product						

Figure 6—The generic Zachman framework

of the higher order model that were not considered in sufficient detail, requiring the review of the higher order model. The sum of these constraint sets establishes the governing constraint set. Thus there is feedback built into the Zachman framework that requires that each model is subject to the informed analysis of the domain experts that are involved with the establishment and use of the models. This is consistent with the engineering principle of 'Design top down, build bottom up'.

The next lower row will again inherit the current constraint set plus the particular row specific constraint set.

This downward propagation establishes a succession of interlinked representative models that are all aligned with the original objectives as modelled in the first row of the Zachman framework.

The Zachman framework as used in information systems architecture

The information system architecture specific Zachman framework is depicted in Figure 7. A cursory examination of the framework will reveal the successive layers of abstraction as well as the way in which each row is aligned with the others.

The Zachman framework originated from studies done in the domains of aircraft manufacturing and the construction of multi-storey high-rise buildings. The adaptation to the information systems domain is a result of the lack of a disciplined approach to a very complex situation that has resulted in vast amounts of money being expended with little or no discernible business benefit being derived. Enterprises across the spectrum have found that the use of the framework has had a marked increase in the understanding of the situation and the subsequent implementation of cost-effective information systems[5].

Using the Zachman framework in mine management

The vast array of influences involved in the modern mining environment presents a very complex situation to a mine manager. The escalating costs of extraction as well as tightening environmental legislation and changing socio-economic parameters requires a new level of thinking to reach equitable solutions that will add value.

More than ever before there is a need to be able to analyse, visualize, understand, synthesize and implement plans that will lead to timeous and cost effective solutions whilst maximizing the enterprise worth.

Figure 8 presents an adaptation of the Zachman framework for use in the domain of mining. Note that there is a large level of correspondence with the Zachman framework for information systems as depicted in Figure 7. It should be evident that the information systems that have been created by using the Zachman framework in Figure 7 actually form part of the production requirements as denoted in column 1 of Figure 8. The reason for this is that most of the cells of row 1 and column 2 of both frameworks are essentially the same. The information system specific framework considers the information requirements that have to be satisfied to support the mining operations whereas the mining specific framework specifies the actual operations and uses information as a process input.

Both Figures 7 and 8 demonstrate the principle of designing top down and building bottom up. Each successive downward transition in the framework has a different level of abstraction and requires new decisions about the governing constraint set. The impact of localized optimizations can be assessed by randomly selecting a cell in the framework and changing the description of the contents.

The first effect will be an impact on the model that was created for that row. As the contents of this cell is a product of the governing constraint set any changes to it would directly impact on the constraint sets of the next higher and lower cells, requiring a reconsideration of these models as well. Being able to retain a holistic perspective whilst focusing on the detail of a situation is one of the great strengths of the use of the framework and could prevent the discontinuities often associated with localized optimizations.

Mapping mine planning to the Zachman framework

From Figures 7 and 8 it follows that the high level process description as used with the Porter value chain belongs in the second cell of the first row of the Zachman framework. This model is generic to the enterprise operation and will feature in every aspect of the supporting infrastructure design.

Depending on the level of abstraction it could be possible to assimilate all of the supporting activities in one Zachman

	What (Data)	**How** (Processes)	**Where** (Locations)	**Who** (People)	**When** (Temporal)	**Why** (Motivation)
Planner model	List of things important to business	List of processes the business performs	List of locations where business operates	List of users/ groups/units of the business	List of business events/ cycles	List of business goals/ strategies
Owner model	Entity relationship diagram	Business processes	Logistics network	Organization chart	Business event/ trigger chart	Business plan
Designer model	Data architecture	Application architecture	Distributed systems architecture	User interface architecture	State transition diagram	Business rules
Builder model	Data design	Application design	Hardware systems design	User interface design	State transition design	Knowledge design
Sub-contractor model	Data definition	Program	Processing/ Network architecture	Access architecture	Timing/interrupts	Rule definition
Product model	Data	Application	Processing/ Communication	Users	Schedules	Rules/strategy

Figure 7—The information system specific Zachman framework

framework as shown in Figure 8. This may however not yield sufficient detail for operational requirements and a common approach is to map each of the supporting activities to its own framework. These individual frameworks will be aligned with each other, and the enterprise goals, as there will be a large overlap in some of the cells as demonstrated with Figures 7 and 8.

Conclusions

The complexity of the modern mining environment requires a new level of thinking. It is important to be able to model the problem space in sufficient levels of detail to obtain a reliable correspondence with reality. The use of classification and visualization techniques like the Zachman framework and value chain concept has the ability to assist in the modelling as outlined in this paper.

The value of a plan may be expressed as a function of the residual problem after the plan has been executed. This could be used as an input to a next iteration through the problem domain in order to arrive at a solution.

Whichever strategy is used to deal with the complexity of mine planning it is evident that there is an overriding requirement that all planning will be done in an interactive way. The development and use of representative models will ensure that the top down approach is augmented by lower order inputs to achieve the alignment of the execution of the plans with the goals of the enterprise.

Acknowledgements

The assistance of Jurgens Visser from AngloGold and Mike Woodhall and his team from GMSI in helping me to understand the mining environment and assisting in the creation of the models is gratefully acknowledged

References

1. Porter, M.E. and Millar, V.E. How information gives you competitive advantage, *Harvard Business Review*, July-August 1985.
2. Dhar, V. and Stein, R. Seven methods for transforming corporate data into business intelligence. *Prentice Hall,* ISBN 0132820064.
3. Zachman, J.A. A Framework for Information Systems Architecture; *IBM Systems Journal*, vol. 26, no. 3, 1987, IBM Publication G321–5298.
4. Sowa, J.F. and Zachman, J.A. Extending and Formalizing the Framework for Information Systems Architecture, *IBM Systems Journal*, vol. 31, no. 3, 1992. IBM Publication G321–5488.
5. ZIFA *Conference Proceedings* 1999. ◆

	What (Things)	**How** (Processes)	**Where** (Locations)	**Who** (People)	**When** (Temporal)	**Why** (Motivation)
Planner model (contextual)	List of the production deliverables	List of processes the business performs	List of locations where business operates	List of users/ groups/units of the business	List of business events/ cycles	List of business goals/ strategies
Owner model (conceptual)	Identification of the production requirement and deliverables	Mining and supporting services process model	Mining and supporting logistics network	Organization chart	Master production schedule	Business plan
Designer model (strategic)	Logical production requirements and deliverable model	Model of the business processes required to manage the ore body	Distributed systems model (ventilation water & electricity reticulation, transport, ore flow etc.)	Strategic structure model (production teams and targets)	Processing schedule	Business rule model (statutory and mining specific rules and regulations)
Builder model (tactical)	Design of supporting infrastructure to establish the production environment	Definition of the business processes required to manage the ore body	Workplace environmental design	Determination of the work team structure (capability and competency requirements	Set development and mining schedules	Business rule design (statutory and mining specific rules applicable to specific task, environment)
Sub-contractor model (operational)	Machines, material, consumables, equipment, transport mechanisms, products	Extraction processes (geology, rock engineering, survey, sampling, development, stoping, cleaning processes)	Workplace (ventilation, heat, humidity, dust, radiation, industrial water, potable water, electricity—power and illumination, communication etc.)	Work teams (mine planners, geologists, surveyors, engineering, development, stoping, cleaning)	Determine priorities of mining schedule subject to operational constraints	Business rule specification (statutory and mining specific rules applicable to specific task, environment)
Product model (execution)	Products (quantity and quality)	Activity	Equipped workplace	Team member	Execution schedule	Strategy (execution of activity within mining rule framework)

Figure 8—The Zachman framework applied to mine planning

2001: China to hold the 1st China International Gold Exhibition

The to-be-opened gold market in China may bring opportunities for South African gold industry

The to-be-opened gold market in China

Gold has a special function as means of currency reserve. And in China, a Socialist planned economy has long been pursued. As a result, for a long period, the gold production in China was closed, and the consumption of gold restrained.

Since late 1970s, China has pursued a policy of 'reform and opening to the outside world', and the market economy has been gradually adopted. In 1999, the coming of China's entry into WTO has quickened the process of the reform and opening of the market of the gold industry—'the last domain of the Chinese planned economy system'.

The national bank—the People's Bank of China—lifted the ban on the silver market as a trial. At the same time, reform in the way of selling and purchasing of gold took place.

To get ready for the opening of the gold market, the Chinese government has speeded up the adjustment of the price of gold to approach the international market price. In 1999, the People's Bank of China adjusted the gold price six times—an unprecedented high frequency.

All kinds of policy seminars like 'China Gold Economy Forum 2000' were held by such organizations as the national departments of gold administration, institutions of economic policy research, mining sectors, gold manufacturers, jewellery retailers, and banks. These seminars have made preparation for the formulation and implementation of policies and regulations for the opening of the gold market.

The Chinese government is planning to establish the first gold exchange in Shanghai. The operation mode of the gold exchange will be similar to other gold exchanges in the world, so that the Chinese gold market can keep pace with the other matured gold markets as soon as possible.

In the year of 2001, China will hold the 1st China International Gold Exhibition, which will speed up the process of market economy of gold.

China—major gold consumer in the world

The people in China have a long history and tradition of using gold as jewellery as well as a means of reserve and precautions.

Statistics by the World Gold Council show that the *per capita* possession of gold in Shanghai—the largest city in China is only 0.28g compared with 0.8g in Hong Kong.

The room for gold consumption is therefore very big.

On December 12, 1999, the Chinese government made its first trial to sell to the public 1500kg 'Millennium Gold Bar'. In one shop in Beijing alone, the average daily (4 hours per day) sale was 200 gold bars. The daily turnover of the 5-day sale is more than US$240,000.

In the past two decades, the annual increase of GDP of China was more than 7%, the *per capita* GDP, more than triple. The total deposit from Chinese residence has increased from US$2.65 billion in the 1980s to the present US$730 billion, up 275 times. According to estimation, after 2000, the *per capita* GDP in China will be between US$3000 and 5000. It is estimated that the sales of gold jewellery will be US$ 1.2 million, and China will become the largest consumer of gold in the world.

The above statistics do not include the consumption of gold in other industries. With the development of Chinese economy, gold will be used more widely in the industries of electronic device, aerospace, chemical industry, building materials and handicrafts.

Gold industry in China facing challenges

China is the fifth largest gold producer in the world. In 1999, the output of gold was 169 tons. There are over 1300 gold producers, employing a workforce of some 300,000. The production system of gold is a complete one. But due to the fact that the industry has long been closed, as soon as the Chinese government opens the gold market, these gold producers will be facing the challenge of survival. The levels of technology, production management, scientific research of the Chinese producers of gold are still far from the international levels.

For instance, the main type of gold deposit in China is vein gold deposit. Yet the depth of mining is only about 600–700 metres, far less than the 5000 metres in South Africa. Consequently, the gold enterprises in China need to exchange and learn from their international counterparts, and introduce state-of-art technology, equipment and management systems.

Business opportunities for South African gold enterprises

South Africa is the world's number one gold producer.

When the Chinese people think of South Africa, they think of gold. This is an indisputable 'brand' effect.

In the great opened Chinese gold market, there exist business opportunities in the following fields for South African enterprises:

Gold products, technology and equipment in the processes of prospecting, mining, ore dressing, smelting, refining, testing, deep processing, and environmental protection, market operation, production management and scientific research; all the above can find opportunities in the huge opened gold market in China.

The politically stable, economically dynamic and legally perfect China will surely enhance the vigour of the South African gold enterprises.

1st China International Gold Exhibition is going to be held in Beijing International Convention Center from June 19 to 22. The exhibition is organized by the China Gold Society and China Council for the Promotion of International Trade Beijing Sub-Council, entrusted by the Gold Administration Bureau of State Economic and Trade Commission, P.R. China. The purpose of the exhibition is multifold: giving impetus to the development of China's gold industry, adaptation to the opening of gold market, extending trade contacts and science and technology exchanges between gold industries in China and other countries, introduction of foreign advanced gold producing technologies to improve China's level of gold production, extending the range of gold application, and stimulating gold consumption.

The exhibit profile covers three categories:

- **Gold products**: pure gold products, gold bar, gold bullion, gold brick, gold coin, gold jewellery, gold watch, gold pen, gold foil painting, fine arts, gold wire, gold foil, gold wire cable for electronics, gold contained welding materials, gold alloy for chemical industry, gold-potassuim cyanide (gold solution) for light industry, and related ceramic and glass products, gold-plated lamp and lighting, utensils, kitchenware, furniture, ornament and other gold products
- **Technology and equipment for gold processing and assay**: technology and equipment for gold assay, technology and equipment for gold smelting and refining, gold jewellery manufacturing technology and equipment, other gold processing technology and equipment
- **Technology and equipment for gold geology, mining and mineral processing**: technology and equipment for gold exploration, technology and equipment for gold mining, technology and equipment for gold processing and metallurgy, technology and equipment for environmental monitoring and protection of gold mines.

During the exhibition period, the organizers will also organize a seminar on 'The Opening of China's Gold Market'. Talks and meetings on trade promotion, investment and technical information exchange will be held to provide good opportunities for economic, trade, scientific and technical cooperation to all parties in the fields of gold production, gold application, gold processing, gold product distribution and gold research.

The Chinese organizers of the exhibition place great importance on the participation of South African exhibitors. The organizers have already sent an invitation letter to the South African Embassy in Beijing to invite South African companies. South African Gold Yard International Exchange Service is entrusted by the organizers of the exhibition to organize exhibitors in South Africa. All interested enterprises are requested to contact Gold Yard at the following numbers:

Tel: (011) 483-2311, Fax: (011) 483-3628, Cell: 0828825214 (Mr Chen), e-mail: goldyard@global.co.za 37–14th Avenue, Houghton 2198, Johannesburg, PO Box 3378, Houghton 2041, Johannesburg.

The deadline for application of the exhibition is April 2 2001. ◆*

SAIMM participation at Electra Mining Africa 2000

Mr John Kaplan of Specialised Exhibition handing our cheque for SAIMM participation at Electra Mining Africa 2000 to our President Dr. Larry Cramer. Looking on with glee are John Cruise and Alastair Douglas. SAIMM have supported Specialised Exhibitions and Electra Mining since 1990

President's Page

Future SAIMM Education Trust Fund

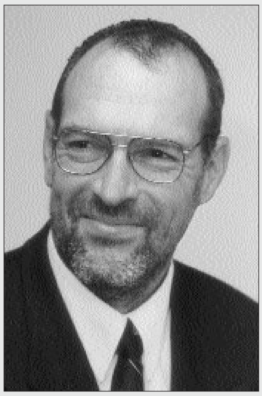
Dear Members,

Most of you will be well aware of the difficulties facing the tertiary institutions in Mining and Metallurgy. These include:

- Reduced government funding for these institutions that has led to belt tightening within the Mining and Metallurgical faculties
- Reduced student numbers due partially to the mining industry's poor image as compared to, for instance, the information technology industry
- Difficulty in attracting and retaining highly qualified lecturing staff in the face of overseas and local competition because of the comparatively low academic salaries.

Industry and various government organizations are aware of these problems and are doing what they believe is possible in the face of many alternative demands on their resources. The SAIMM has also done what it can to facilitate the identification of the problems and the possible solutions to the issues surrounding careers in Mining and Metallurgy. Indeed the SAIMM intends to continue to assist wherever it has the resources to do so.

Often students do not take up Mining and Metallurgical careers because of a lack of funds for their university/technikon education; quite frankly they go where the money is. Many companies are reluctant to fund a student in his/her first year because of the high dropout rate; this of course does nothing to attract potential students to follow in our career path. The SAIMM membership may be able to assist in this area and thus contribute to the well-being of the industry that has given them a livelihood for so many years. In order to give company and individual members the opportunity to help new students in Mining and Metallurgy to finance their education, the SAIMM is setting up a SAIMM Education Trust Fund. This trust fund will be designed to give tax relief to the contributors and will dedicate the funds it receives to deserving students at South African faculties of Mining and Metallurgy.



We are planning to have the Trust established for mid-year 2001 and will be asking members to support this with a donation (anything from R20 upwards) when we process next year's invoices for membership fees. We cannot hope to contribute to the same extent as do the larger mining companies who fund many students each year but our contribution will be important to a few students each year who otherwise may not have been able to pursue their chosen career in Mining or Metallurgy. Please give freely of your support, it will be greatly appreciated. ◆

Dr L.A. Cramer
President